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Chemical Engineering

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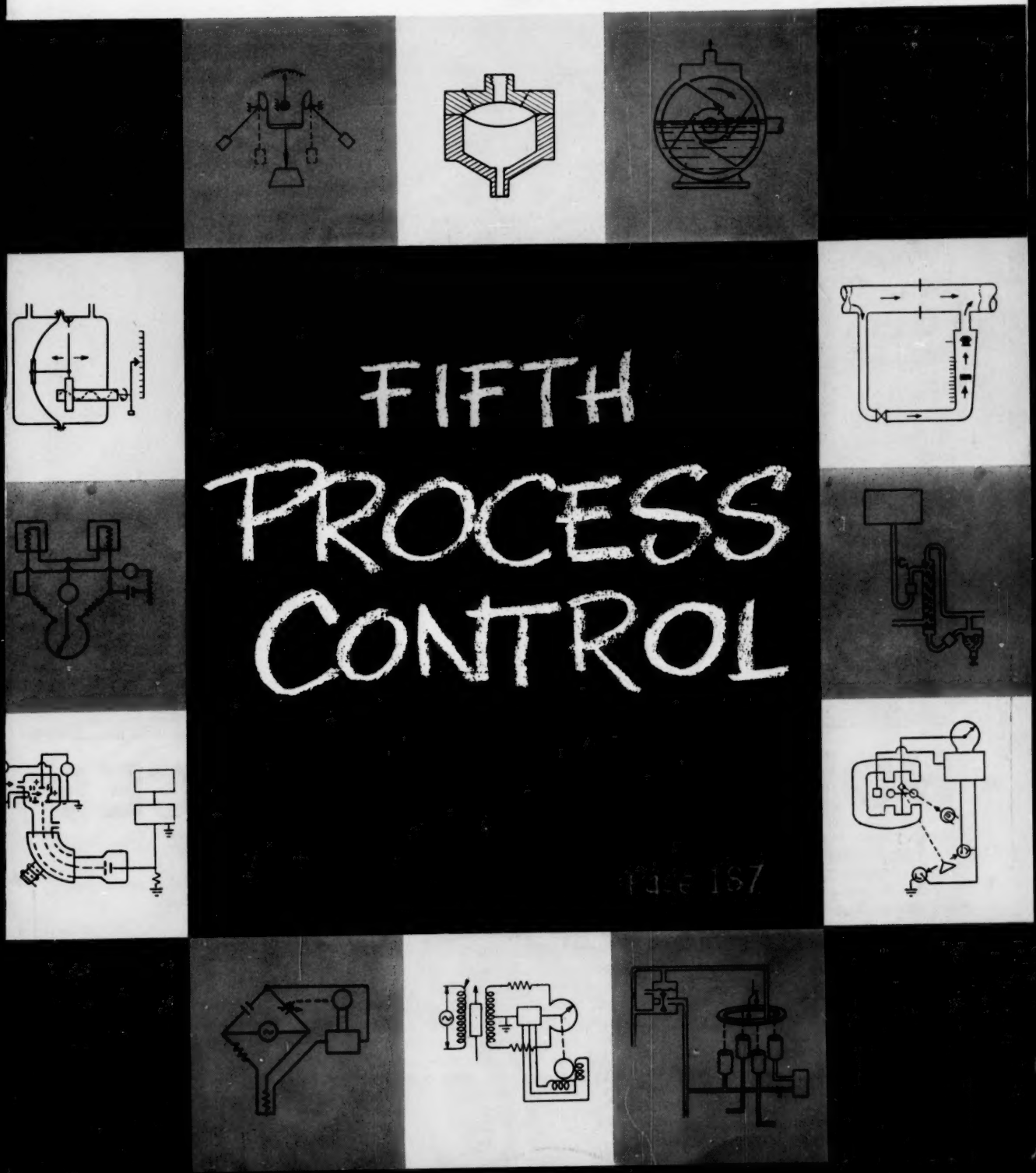
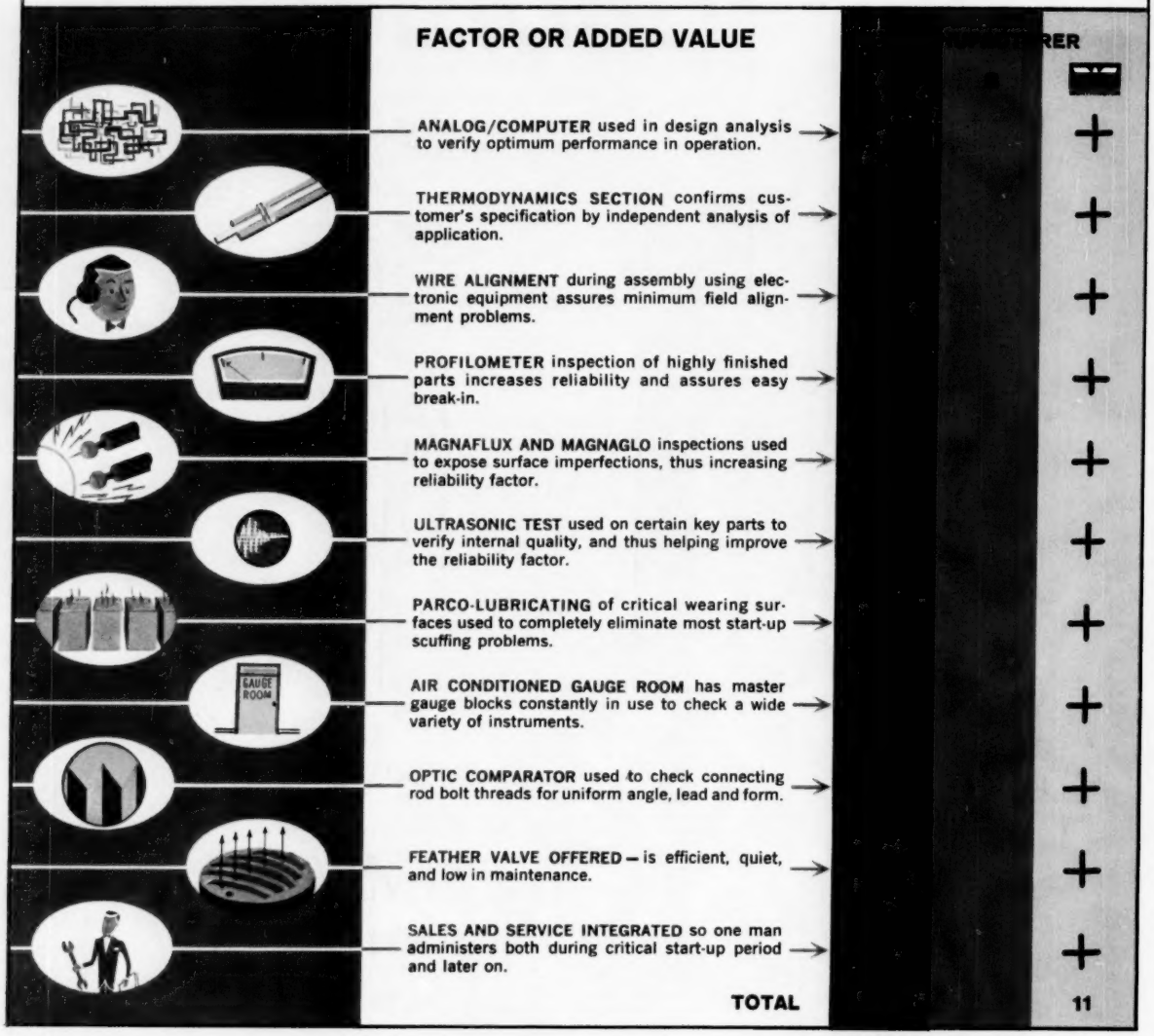


COMPRESSOR QUOTATION EVALUATION


FACTOR OR ADDED VALUE
RER
ANALOG/COMPUTER used in design analysis to verify optimum performance in operation.
THERMODYNAMICS SECTION confirms customer's specification by independent analysis of application.
WIRE ALIGNMENT during assembly using electronic equipment assures minimum field alignment problems.
PROFILOMETER inspection of highly finished parts increases reliability and assures easy break-in.
MAGNAFLUX AND MAGNAGLO inspections used to expose surface imperfections, thus increasing reliability factor.
ULTRASONIC TEST used on certain key parts to verify internal quality, and thus helping improve the reliability factor.
PARCO-LUBRICATING of critical wearing surfaces used to completely eliminate most start-up scuffing problems.
AIR CONDITIONED GAUGE ROOM has master gauge blocks constantly in use to check a wide variety of instruments.
GAUGE ROOM
OPTIC COMPARATOR used to check connecting rod bolt threads for uniform angle, lead and form.
FEATHER VALVE OFFERED — is efficient, quiet, and low in maintenance.
SALES AND SERVICE INTEGRATED so one man administers both during critical start-up period and later on.
TOTAL
11

HOW MUCH IS A PRICE?

Above, you see one buyer's check-off of the hidden values buried in a Worthington compressor quotation. It helped indicate the true value of the Worthington offering. But more important than this check-off is the subject involved.

Today's rising costs and minimum profits compel every buyer to scrutinize compressor prices as never before. The problem in determining the true value of an offering is more important and, frequently, more difficult.

What's the answer? For more complete price evaluation, we suggest that you look for the "hidden value" in each manufacturer's offering—in far more detail than above. You can be sure that the true prices will separate very quickly, because "hidden" values vary sharply in the compressor market today.

To help you find, isolate and evaluate compressor offerings, we have prepared an objective "Compressor Evaluation Guide." This booklet points out the six key areas of judgment required for compressor evaluation and details them in full. Ask your Worthington Representative for this booklet or write Worthington Corporation, Dept. 36-17, Clinton Street and Roberts Avenue, Buffalo, N.Y. In Canada, Worthington (Canada) Ltd., Brantford, Ontario.

WORTHINGTON

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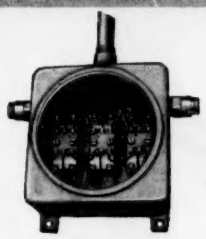
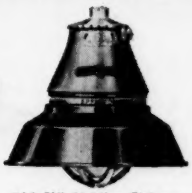
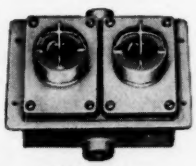


Type "GUB" Unilets—
where junctions
are required

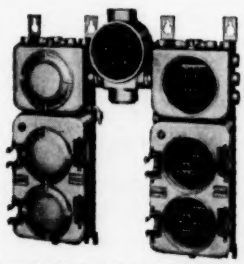


"AA-51" Lighting Fixtures—
incandescent or mercury
vapor lamp type . . .
more light, at less cost



"EFD" Series—
dust-tight pilot light
and switch Unilets

"SFN" Sealing Unilets—
for sealing off conduit
systems at
required points



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With Covers Removed.
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15 to 30 ampere ratings

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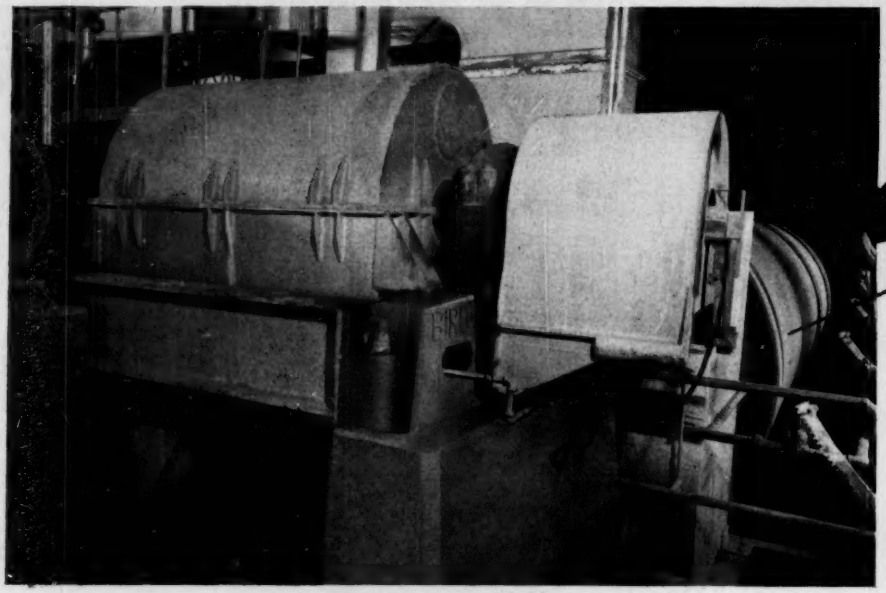
Explosion-Proof Reolites

To turn Waste into Profit, Kiln Feed for Lime Recovery for Reburning is Strictly from the Birds



BIRD
CONTINUOUS
CENTRIFUGALS

have made reburning of Ca CO_3 or Ca $(OH)_2$ for re-use in paper mills, water softening and acetylene plants immeasurably more profitable.

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These Birds virtually look after themselves, running continuously with the barest minimum of attention. Their operation can readily be made completely automatic and tied in with kiln control. Maintenance expense is no more than a penny per ton.

Perhaps *your* solid-liquid separations hold equal promise of improvement and cost reduction. The Bird Research and Development Center is well equipped to help you find out.

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Chemical Engineering

June 12, 1961

CHEMICAL TECHNOLOGY FOR PROFIT-MINDED ENGINEERS

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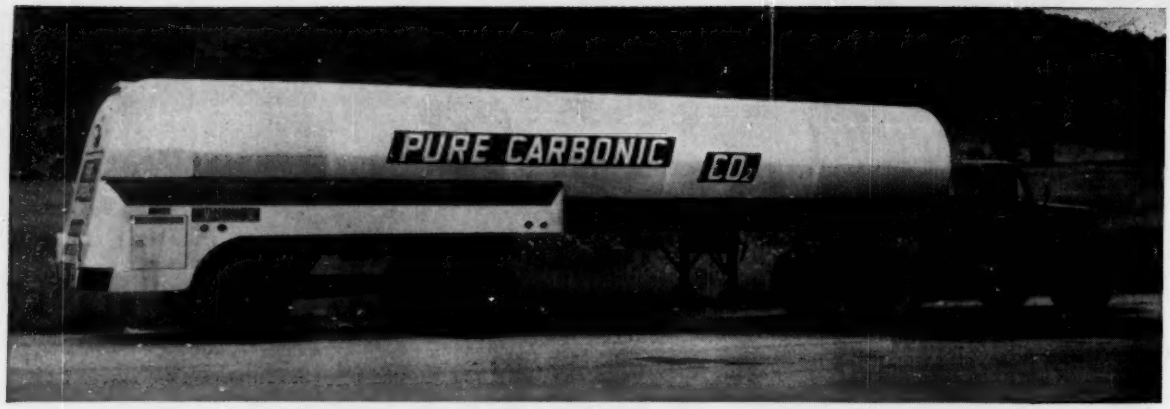

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Chemical Engineering
JUNE 12, 1961

Process Control

Process control is no longer the stranger to chemical engineers that it was when *Chemical Engineering* (then *Chem. & Met.*) initiated its series of major reports on the subject in 1929. Our fifth such effort (pp. 187-238) will update your knowledge of both the principles and equipment of process control.

TRACING A PATH AROUND THE LOOP

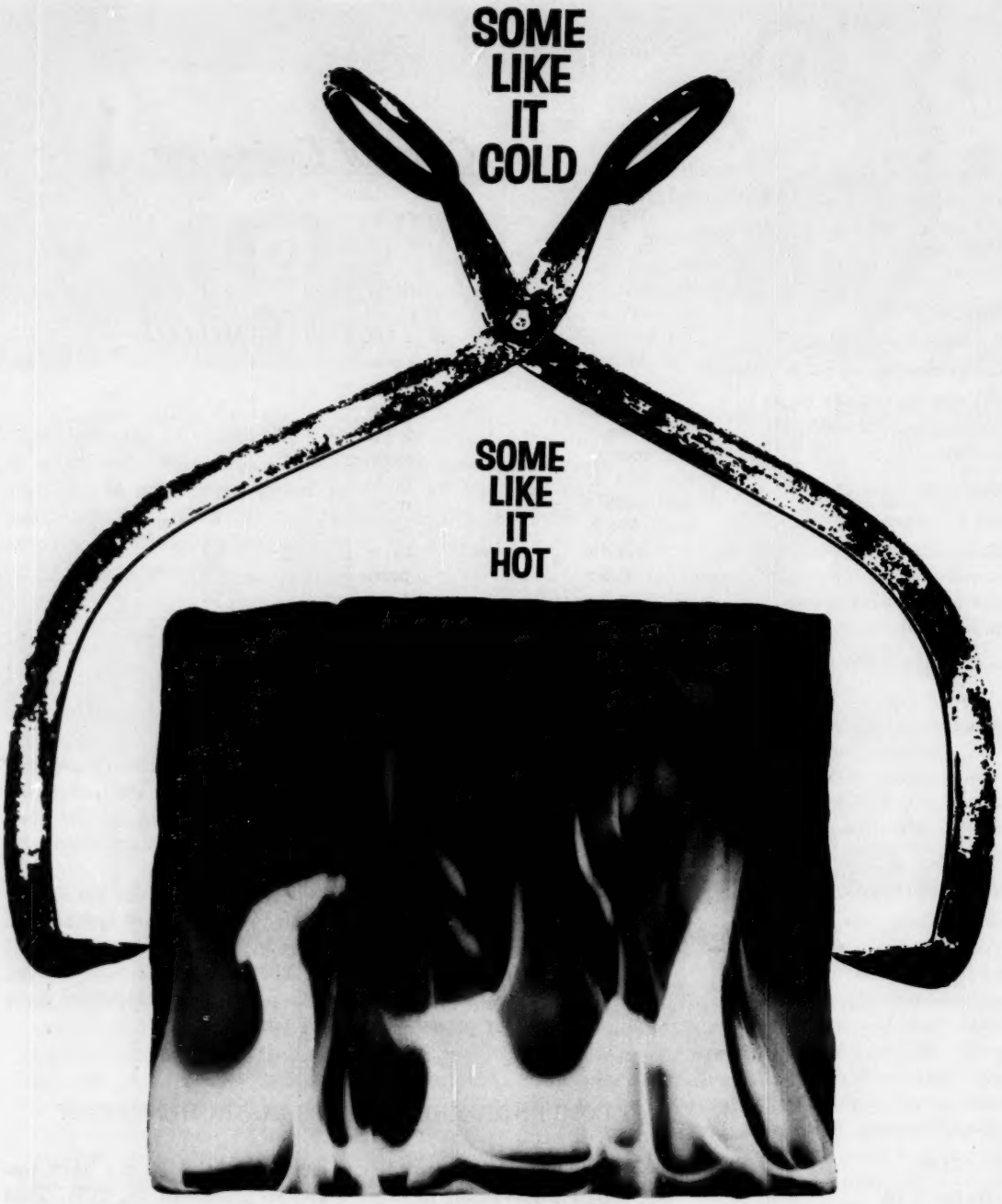
Five separate articles tackle various parts of the feedback control loop. First is a summing up of some useful economic tips (p. 189), followed by a description of how to analyze dynamics of a typical fluid process system (p. 193). There's never good control without good measurement, so the next article (p. 199) records progress in use of primary elements.

Knowledge of operating-variable relationships can save processing dollars when coupled with proper control techniques. The fourth article shows the way in its discussion of special-purpose analog controllers (p. 205). And the final article, on plant testing, shows how to get the experimental data you need for process dynamics (p. 209).

COMPENDIUM OF PROCESS INSTRUMENTATION

Because of its proved popularity in the past, we have updated our guide to process-control elements (p. 213). This guide compresses a wealth of helpful information into its 26 pages. Taken together, the guide and the accompanying articles constitute a valuable permanent reference library on process control.

For Letters: Pro & Con, *see new location*.....PAGE 7



Either way . . . you'll like it at only $35.95 list. The Model "Y" Dial Indicating Thermometer. Available in four temperature ranges. From minus 40° to 140° F; 0° to 160° F; 30° to 240° F; or 200° to a 450° F. This vapor pressure actuated thermometer is very versatile. Use it anywhere! Mounting problems? Not a one! It has a universal mounting bracket. Tilt it 60° forward. Or 90° to either side. Any way you look at it . . . you'll get an easy-to-read eye-full. Its dial is large . . . with raised graduations to reduce parallax reading error. Each is individually calibrated for maximum accuracy. Its six foot capillary is flexible for remote reading. The chromium-plated, hard drawn brass case is weatherproof. The inner movement is protected for life against moisture and dust. For further information about the precision Model "Y" and the complete line of Autolite instruments and accessories just drop us a line. Write today to . . . **THE ELECTRIC AUTOLITE CO.** INDUSTRIAL INSTRUMENT DIV. • PORT HURON, MICH.

Pro: Better Corrosion Data

Sir:

I readily agree that "Polyesters Aren't All Suited for Corrosive Media" (Apr. 3, p. 182). But I question the suitability of your published information for intelligent selection of a polyester resin for corrosive service.

Such resins are generally used in combination with glass reinforcing to form a complex laminated structure of unusual properties—properties, including corrosion resistance, which neither the reinforcing nor the resin necessarily possess separately.

For example, if one were to extend the information presented on castings based on Bisphenol A to laminates based on the same resin, it would be quite dangerous. Laminates will not be suitable for a corrosive service, in many instances, even though the castings exhibit what appears to be suitable resistance in the same environs. The data presented could seldom, if ever, be used to provide design information for practical use of a rigid polyester.

W. A. SZYMANSKI
Hooker Chemical Corp.
Niagara Falls, N. Y.

Sir:

Contrary to Mr. Szymanski's first paragraph, our data *are* suitable "for intelligent selection of a polyester resin for corrosive service." The article clearly indicates that "polyesters aren't all suited for corrosive media" by showing that castings of various types and grades of polyesters have drastically different rates of loss of flexural strength upon exposure.

With regard to Mr. Szymanski's point that casting data cannot be used to predict laminate performance:

1. The polyester resin portion of a laminate provides the corrosion protection, and the glass reinforcement provides the strength and toughness. In a properly prepared corrosion-resistant laminate, a resin-rich surface is required to insure maximum protection for the glass. The resin-rich surface is essentially equivalent to an unreinforced casting. Thus, data on castings are definitely significant, since if the resin-rich surface of the laminate failed, the laminate would be subject to rapid deterioration.

2. We have data for well-prepared laminates which show direct correlation between casting performance and laminate performance. These data are being prepared for publication.

3. We admit that improperly prepared laminates will give poor results regardless of the resin used. We have constantly cautioned the engineer to beware of poor workmanship and have urged him to deal with well-established fabricators. We have also warned against extrapolation of corrosion data to other concentrations or temperatures and strongly recommend immersion of test panels in actual solutions prior to purchasing equipment.

We have been working constantly for the past three years to develop and correlate laboratory data in this field. Prior to our work, "corrosion tests" could mean 2-hr. boil, 24-hr. boil and, in some cases, 30-day exposures. Since corrosion-resistant equipment is designed to last 10 to 20 years or more, we designed our exposure studies to last for one year or more under the most severe conditions possible. We have faithfully reported our data at the two most recent annual SPI meetings.

S. S. FEUER
Atlas Powder Co.
Wilmington, Del.

Pro: Evening Graduate Work

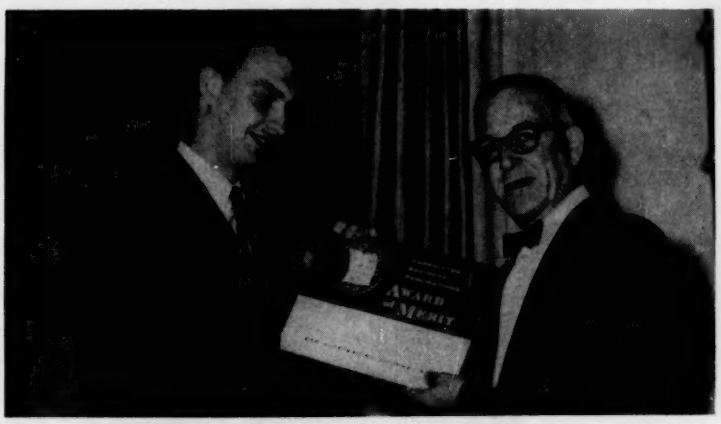
Sir:

In your Mar. 6 issue (p. 58) you mention that there is a drop-off in enrollment for master's degrees in chemical engineering.

Considering that the majority of chemical engineers work during the daytime, could this be due to lack of opportunity for evening study? It seems that in many localities where chemical engineers are em-

(Continued on page 310)

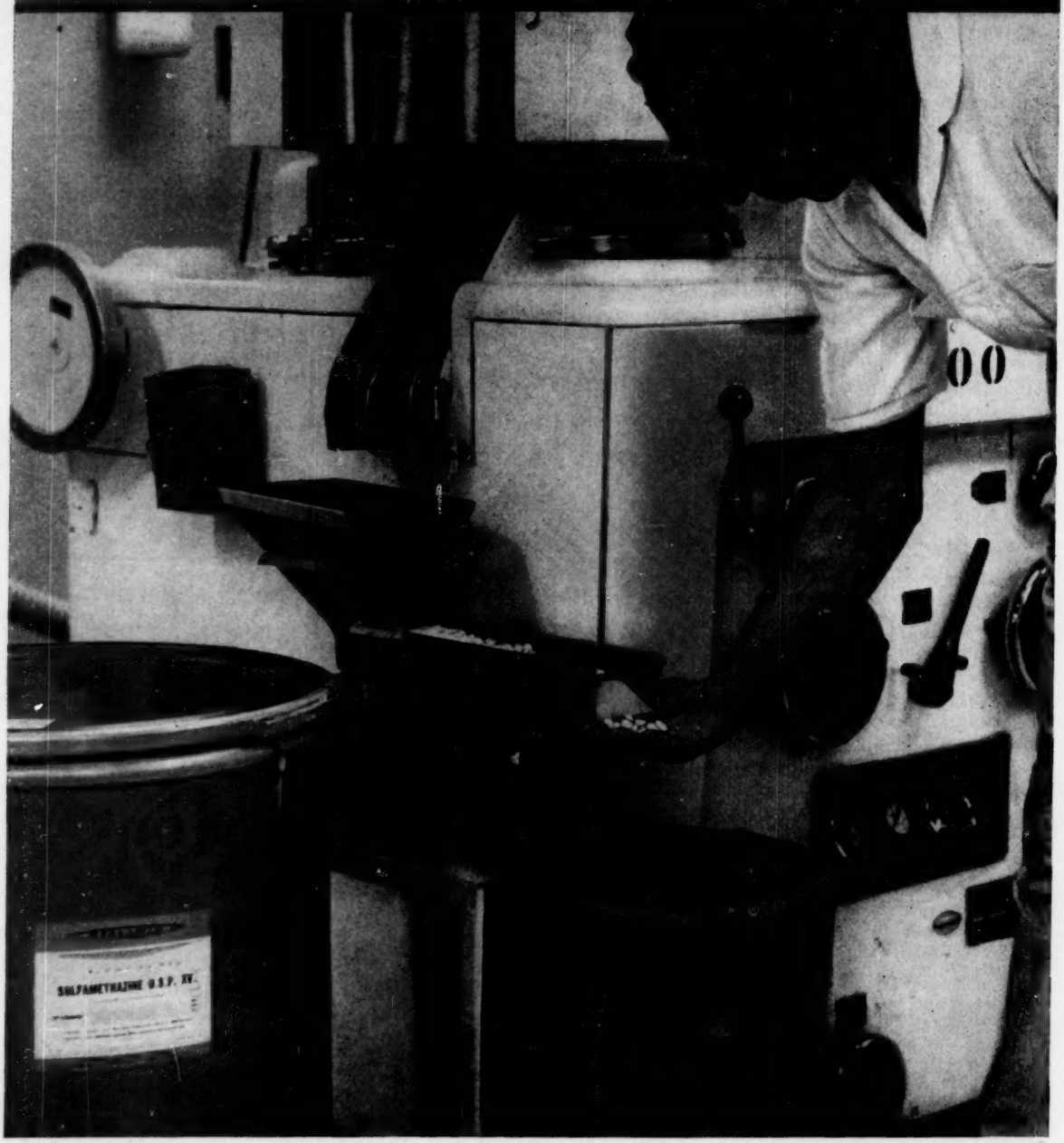
CE editor accepts award for editorial achievement



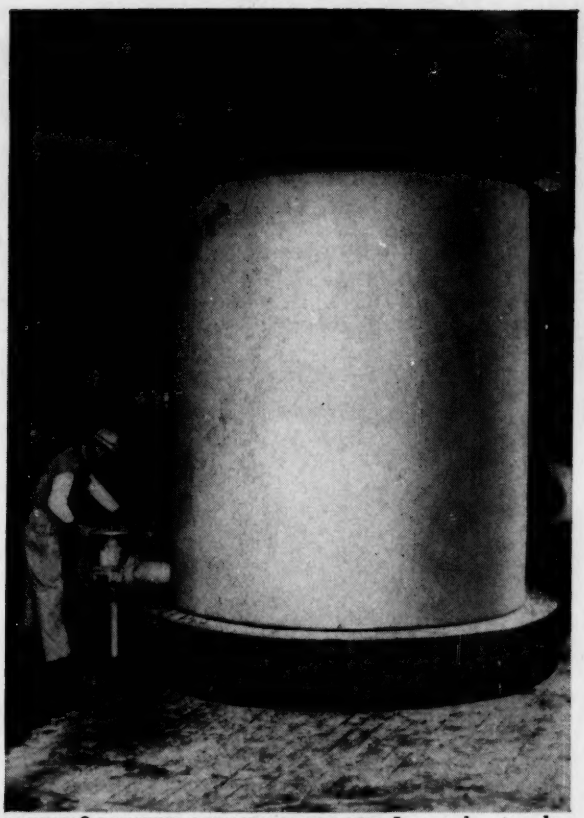
Assistant Editor Roland A. Labine accepts, on behalf of the editorial staff of Chemical Engineering, the Jesse H. Neal Award of Merit for Editorial Achievement. This award, sponsored by Associated Business Publications, recognized the editorial excellence of Labine's article on "The Truth About Industrial Spying," published in CE, Feb. 20, 1960. Presenting the award at an ABP meeting at the Biltmore Hotel in New York on April 24 was H. C. McDaniel (above, right) of Westinghouse Electric, member of the board of judges.

CYANAMID

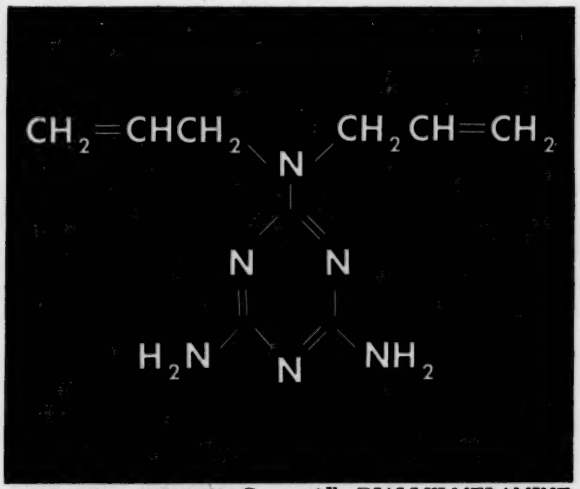
Chemical Newsfront



CHEMICALS BY THE CARLOAD. Fine chemicals in bulk—supplied by Cyanamid's Fine Chemicals Department. With them goes uniformity, quality and protection against variations in potency—properties "built in" by Cyanamid to assure the finest sulfonamides, antibiotics, and other products made for the pharmaceutical manufacturing industry. **(Fine Chemicals Department)**



LAMINAC® POLYESTER RESIN FIGHTS OFF ACID. It costs less to solve industrial corrosion problems with Cyanamid's LAMINAC. The wash acid storage tank above is made of glass-reinforced LAMINAC—resistant to corrosion by phosphoric acid, sulphuric acid and gypsum. Tough corrosion problem? Look into LAMINAC.
(Plastics and Resins Division)



EPOXY RESIN CATALYSIS. Cyanamid's DIALLYLMELAMINE (DAM) provides fast cure for epoxy resins above 130° C, coupled with outstandingly long pot life at room temperature. The residual allyl groups may be reacted with other unsaturated systems to modify the epoxy product. **(Market Development Department)**

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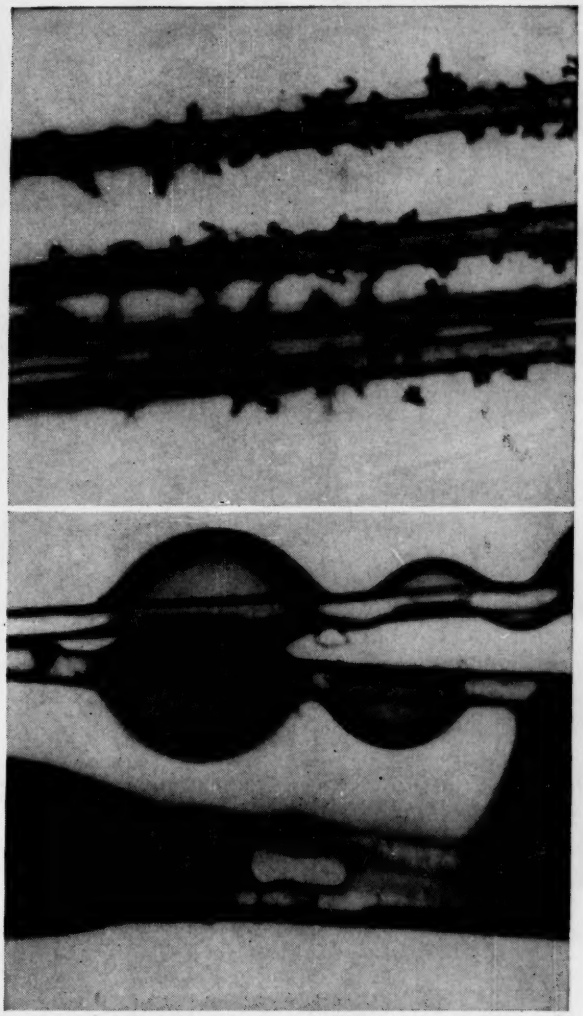

CYANATEX® DYEING ASSISTANT EM DYE-SOLVENT CARRIER speeds penetration of dye. Above, Cyanamid's Cyanatex has formed colored globules that attach readily to polyester fibers. There is no dye-carrier precipitate build-up as on the fibers at top. Because Cyanatex diffuses more readily into the fiber, polyesters, triacetates and acetates achieve brighter, heavier shades. **(Dyes Department)**

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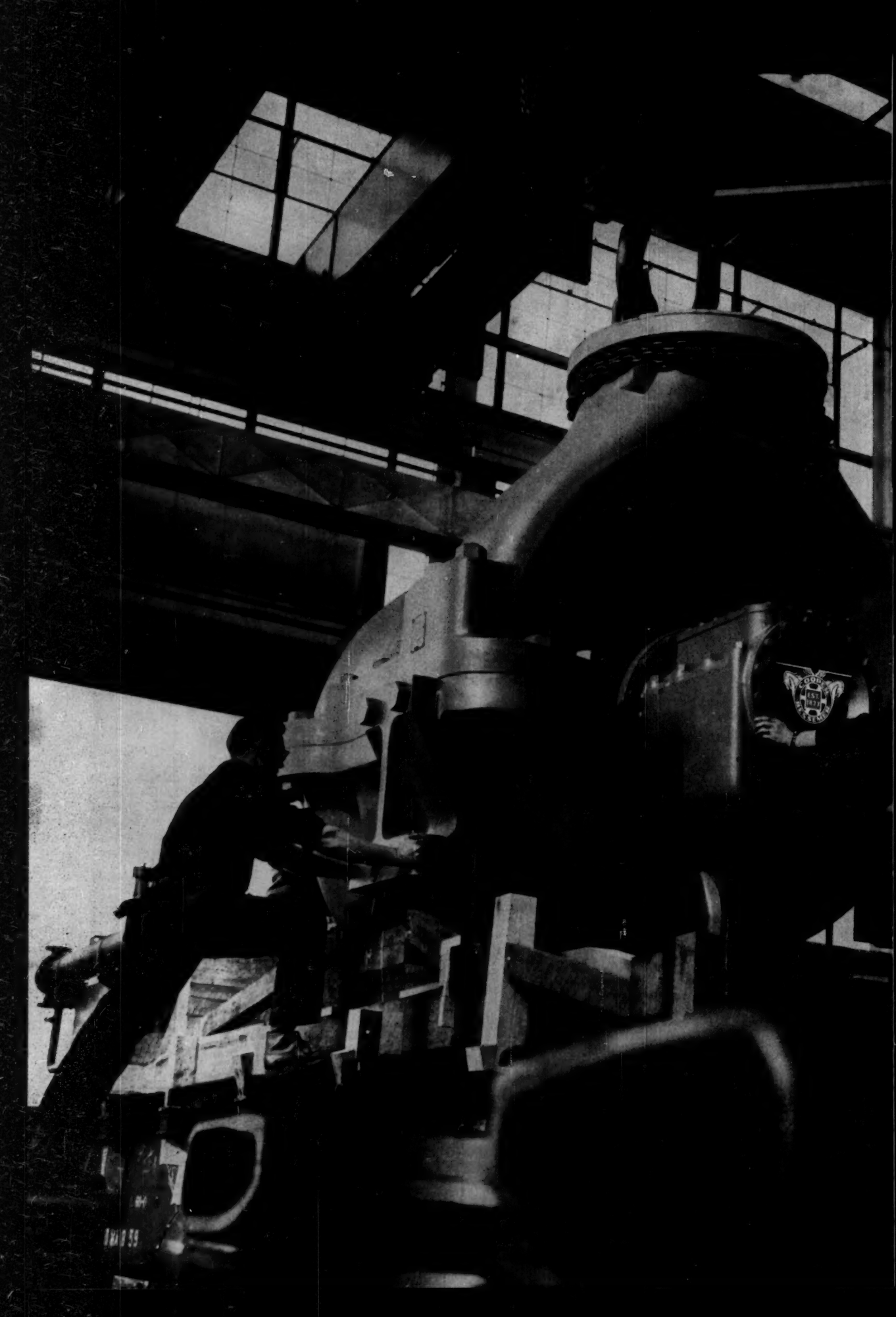
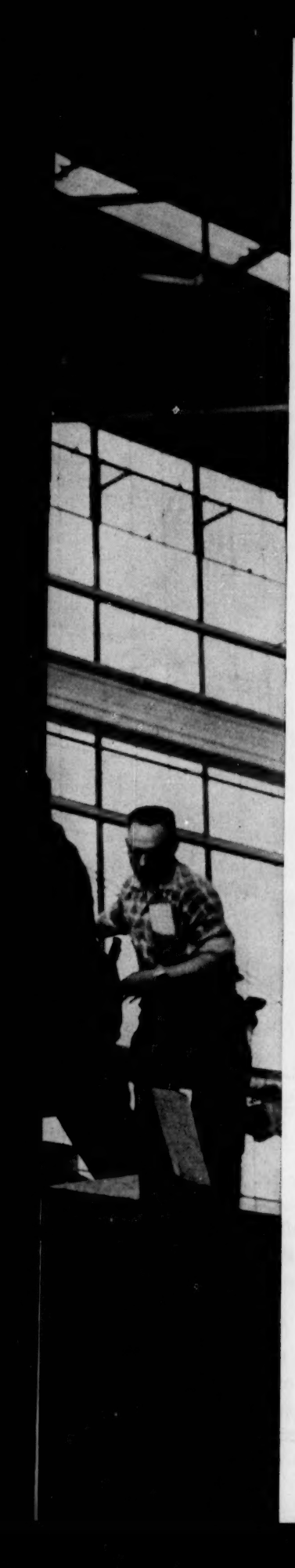




Another Cooper-Bessemer centrifugal goes to work

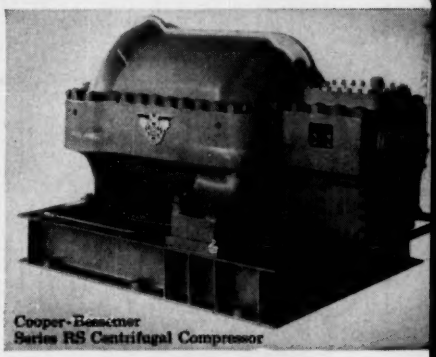
Here's proof of compressor economy

When your plans call for centrifugal compressors, it will pay you to be guided by the experience of others. Take a tip from the *repeat order* record of Cooper-Bessemer centrifugals as a sure sign of *cost-saving performance.*

The Cooper-Bessemer centrifugal shown here is being shipped to a chemical manufacturer for big volume compression. They *know* how reliable C-B centrifugals really are. Another unit has been operating there 'round-the-clock for two years, as part of a process, where constant availability is a *must.*

Repeat orders for Cooper-Bessemer centrifugal compressors have come time and again from many progressive companies.

Many features account for the stamina and dependability of Cooper-Bessemer centrifugal compressors—such as their rugged all-welded impellers, and unique shaft sealing. Find out how they can pay off for you. Call our nearest office or write



Cooper-Bessemer
Series RS Centrifugal Compressor

BRANCH OFFICES: Grove City • New York • Washington • Gloucester • Pittsburgh Mount Vernon • Detroit • Chicago • Minneapolis • St. Louis • Kansas City • Tulsa New Orleans • Shreveport • Houston • Greggton • Dallas • Odessa • Pampa Casper • Seattle • San Francisco • Los Angeles

SUBSIDIARIES AND DIVISIONS: Cooper-Bessemer International . . . New York
Cooper-Bessemer, S.A. . . . Chur, Switzerland • The Hague, Netherlands • Mexico City Buenos Aires, Argentina • Anaco, Venezuela • Caracas, Venezuela • San Juan, Puerto Rico
Cooper-Bessemer of Canada, Ltd. . . . Edmonton • Calgary • Toronto • Halifax • Stratford
The Rotor Tool Company . . . Cleveland
C-B Southern, Inc. . . . . Houston

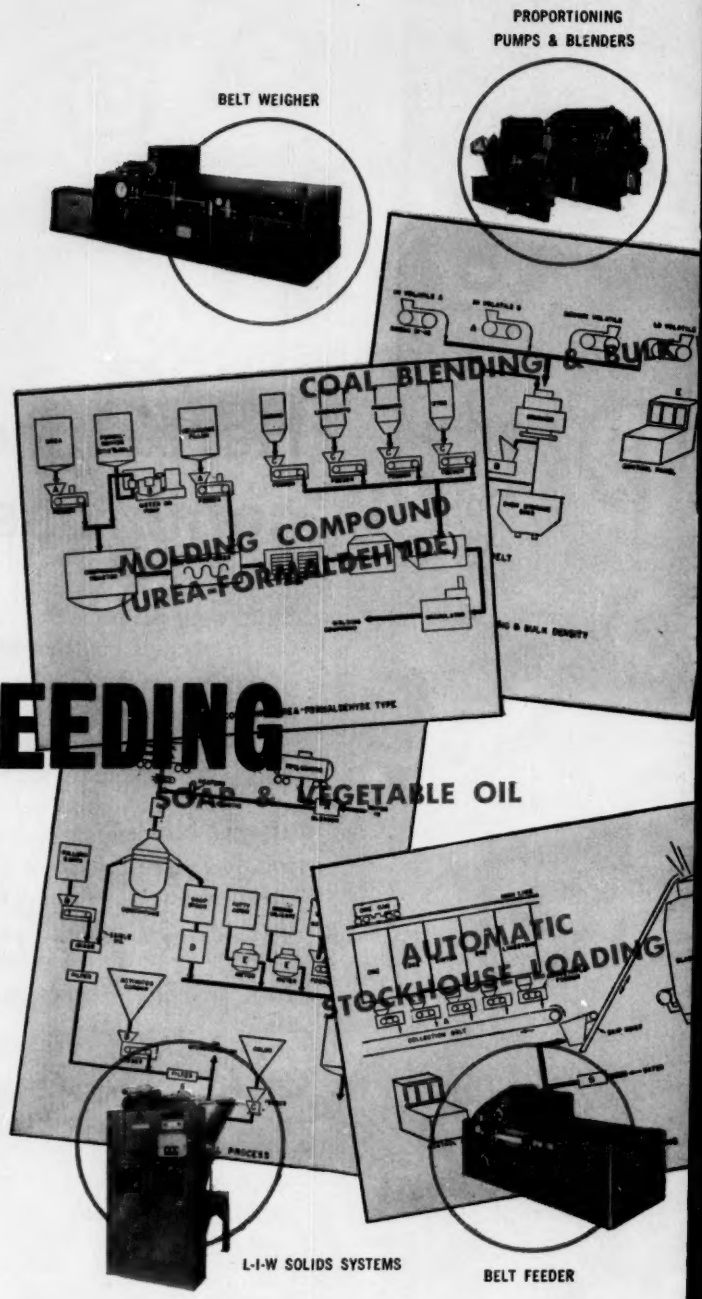
Cooper Bessemer

GENERAL OFFICES: MOUNT VERNON, OHIO

COMPRESSORS: RECIPROCATING AND CENTRIFUGAL
ENGINES: GAS - DIESEL - GAS-DIESEL
JET-POWERED GAS TURBINES

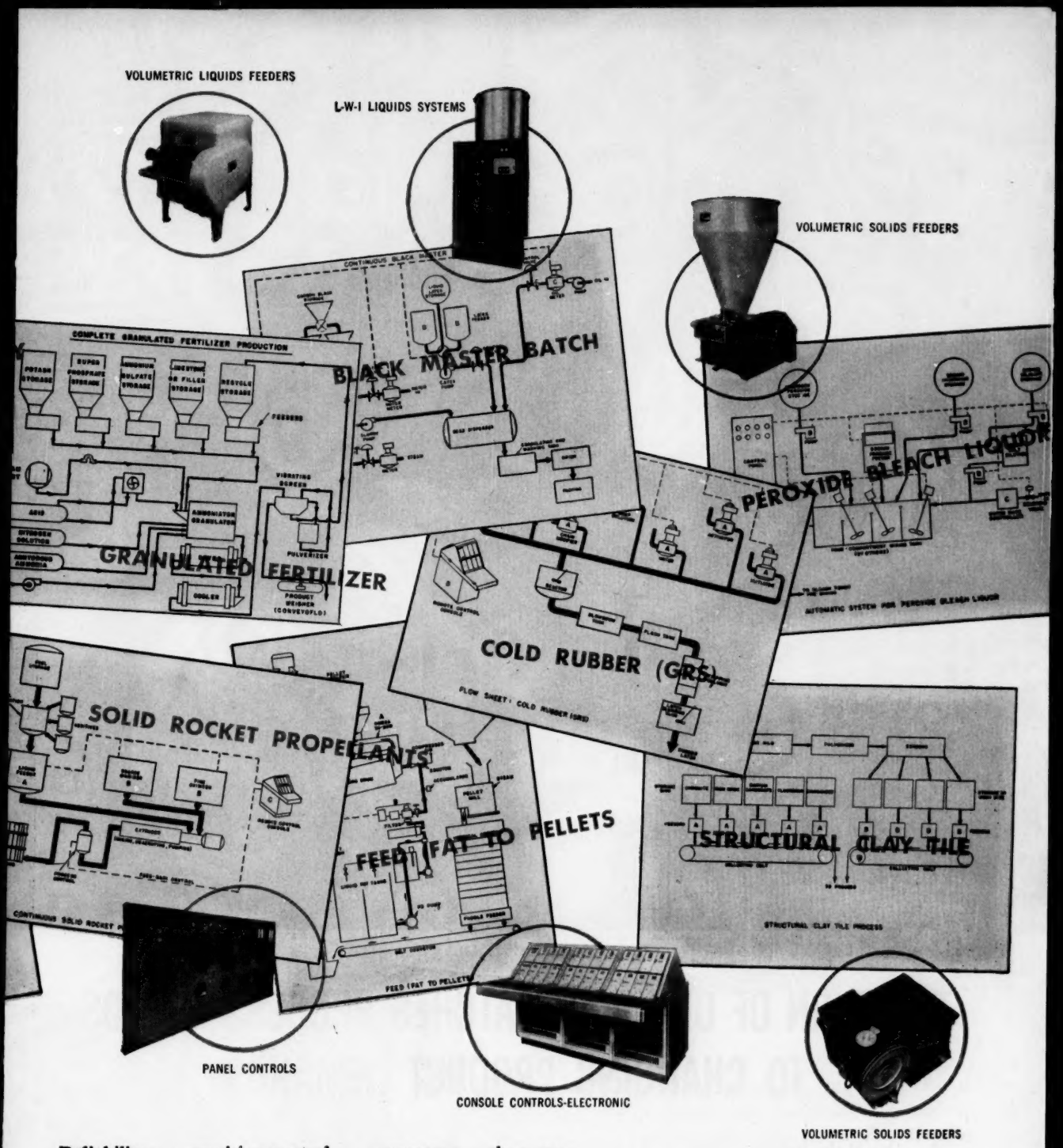
B-I-F

WHEREVER AUTOMATIC, **CONTROLLED FEEDING** OF LIQUIDS AND SOLIDS IS INVOLVED



Controlled feeding is a B-I-F specialty . . . whether it involves a single unit or a fully integrated system with provision for remote control. Thousands of installations throughout the chemical processing industries prove B-I-F's ability to handle chemicals of all kinds . . . including corrosive, toxic or hazardous types.

B-I-F has over 30 years of actual field experience in controlled feeding systems for solids and liquids. And . . . B-I-F manufactures the most complete line of volumetric and gravimetric feeders. The resulting application flexibility can give you a performance-proved system . . . based on your most exacting needs.



Reliability . . . precision control . . . accuracy . . . these are the keys to profitable batch or continuous processing. No one type of feeder or feeding system can meet every processing requirement. B-I-F's application knowledge assures the exact equipment for end product quality . . . minimum production cost . . . minimum waste!

B-I-F **Industries**

BUILDERS-PROVIDENCE • PROPORTIONEERS • OMEGA

METERS • FEEDERS • CONTROLS / CONTINUOUS PROCESS ENGINEERING

YOU NAME IT! When it comes to controlled feeding of liquids and solids, a B-I-F specialist is ready to recommend and furnish estimates. See Chemical Engineering Catalog or Sweet's Plant Engineering File for your nearest B-I-F representative . . . or write **B-I-F Industries, Inc., 369 Harris Avenue, Providence 1, R. I.**

THE TURN OF ONE DIAL MATCHES PROCESS SPEEDS TO CHANGING PRODUCT DEMANDS

The value of the Reliance Super 'T' V★S Drive on this extruder is in its ability to produce and hold accurately the wide range of specific speeds necessary to handle a variety of plastic materials.

Polyethylene, polystyrene, nylon and PVC are among the plastics that are color-compounded, heated and extruded for pelletizing. Each one calls for a different machine speed and setting. Motor operating speeds can be varied from 145 to 2000 rpm . . . and within the range, the V★S Drive maintains the exact speeds needed to extrude and pelletize each type . . . and this even includes zero speeds for set-up.

These perfectly controlled speeds and the 24-hours-a-day, 7 days-a-week use demanded by this plant's production schedule are the basic reasons why Plastic Materials and Polymers, Inc. has standardized on Reliance V★S Drives in all three of its plants.

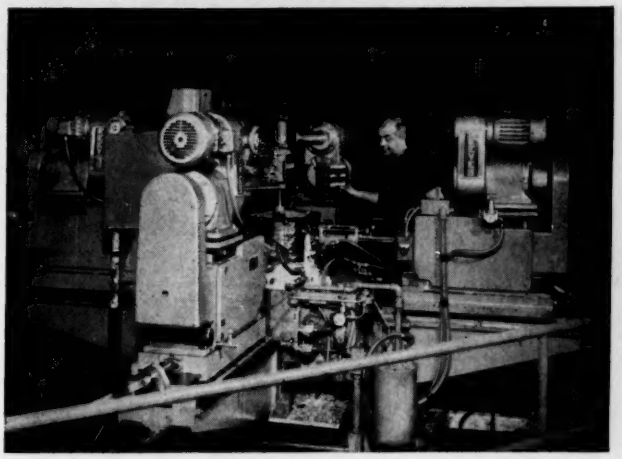
BUILDERS OF THE TOOLS OF AUTOMATION

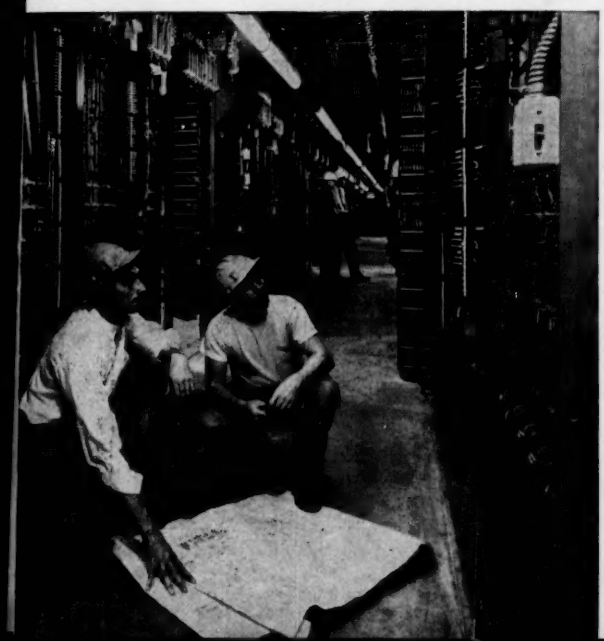
A-1683

ONE SELF-CONTAINED, COMPACT POWER PACKAGE. This MASTER GEARMOTOR has been operating outdoors for 5 years regardless of weather. It has no exposed high speed couplings, no V-belts, chains or sprockets. Engineering and assembly costs are reduced. You can simplify installations and save space with vertical, horizontal and flange mountings; output shaft over, under, left or right. Ratings 1/8 to 125 hp. in right angle, parallel or in combination. Right angle ratios are available up to 96:1; parallel 120:1. Bulletin E-2409.

CONTOUR EPOXY-COATED TO ELIMINATE ENCAPSULATION CRACKING. New RELIANCE ENCAPSULATED MOTOR . . . gives you positive protection from dust, dirt, acid and water. Unlike other heavy molded coatings, stator windings are vacuum-impregnated with epoxy resin at a uniform thickness, follow the contour of the windings. You get maximum flexibility, tensile and bond strength, plus quicker cooling . . . all vital to superior motor performance. Bulletin B-2108.

INFINITELY VARIABLE OUTPUT SPEEDS AT LOW COST. REEVES MOTODRIVES, shown here powering this 4-position drilling and boring machine, are used extensively for hundreds of production needs. Horsepower ratings from ¼ to 40, speeds from 1.71 to 4660 rpm. Speed variation ranges from 2:1 to 10:1. Available in hundreds of space-saving assemblies . . . with manual, remote or automatic process control (Airtrol). Bulletin M-592.

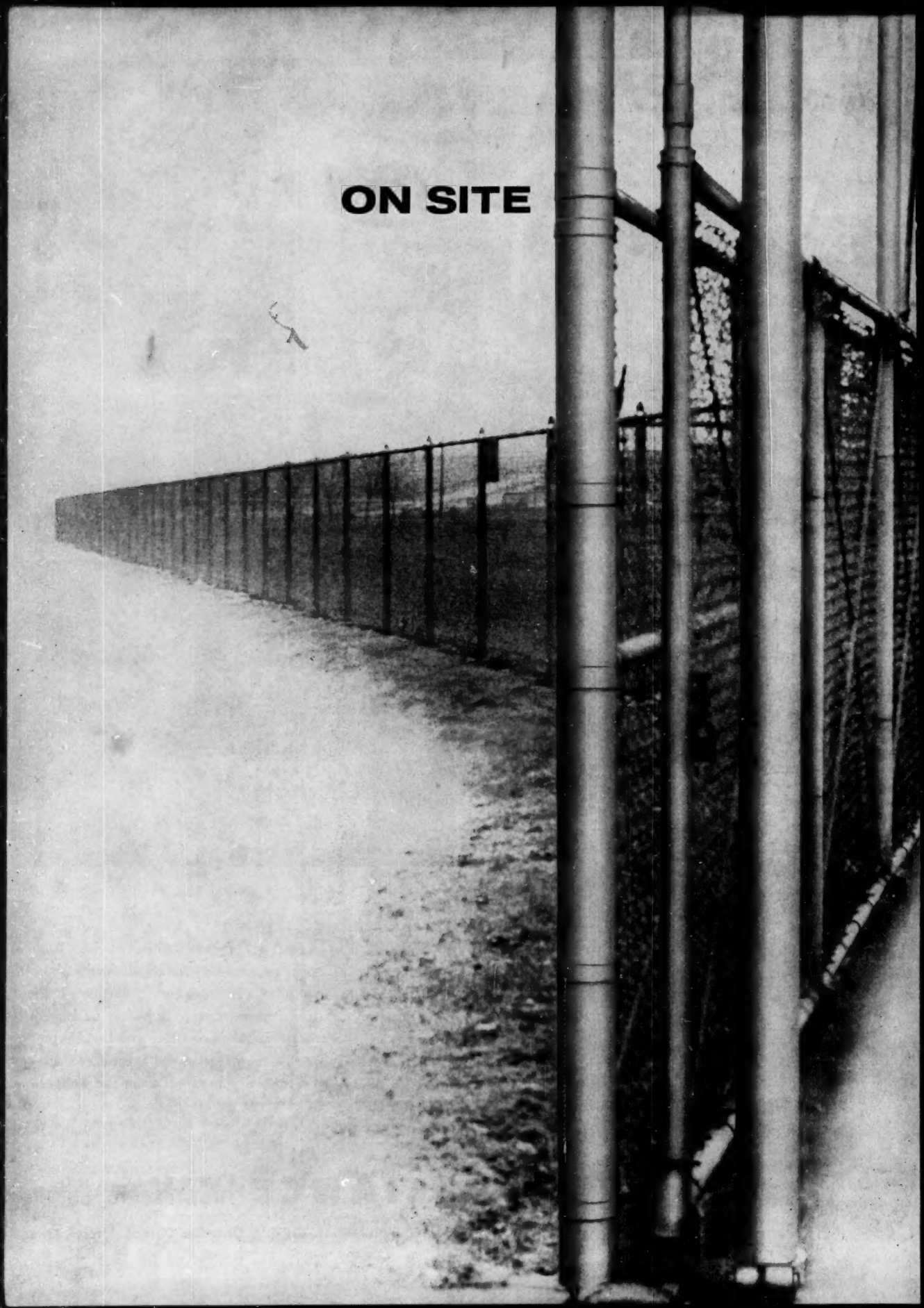




TOTAL SERVICE is an integral part of every Reliance product, from engineering and start-up assistance to maintenance and renewal parts. The photo shown here is typical of a Reliance Service Engineer's on-the-job availability—for maintenance and consultation on knotty problems. Every Reliance Sales Engineering Office and Distribution Center—nationwide—gives you the attention and experience necessary to assure the top performance you expect from the Reliance equipment you buy.

RELIANCE ELECTRIC AND ENGINEERING CO.

DEPT. 13-6, CLEVELAND 17, OHIO • Canadian Division: Toronto, Ont.


ON SITE

...OR ACROSS THE FENCE

AN AIRCO OXYGEN PLANT SAVES YOU MONEY

Buy oxygen as you would buy other chemical commodities—let Airco build and operate a tonnage oxygen plant for you.

Airco will build on your site, or on property we acquire adjacent to your plant. Either way, you are assured of all the oxygen you require . . . at a steady rate . . . at a firm, fair price. And if you have a use for nitrogen in one of your processes, that too is available from the oxygen plant.

Consider the advantages of having Airco supply your oxygen on this basis:

No Capital Investment. Airco finances the oxygen plant, whether it's on property leased from you or on our over-the-fence site. You pay only for oxygen, just as you would for natural gas piped into your plant. The capital required for the oxygen plant is available to you for other ventures.

Proven Technology. Airco draws on more than 40 years' experience in low-temperature technology . . . design, engineering and construction proficiency that has dotted the country with oxygen and other industrial gas plants of all sizes. Our processes are efficient . . . our plants economical . . . our engineers proficient in air separation.

Oxygen Available Fast. Airco has the personnel to bring a plant onstream fast . . . will meet any construction schedule promised.

Assured Low Cost. Industrial gases are our business, so there's no first-plant guesswork on oxygen costs. We give you a firm contractual price that reflects the economies that come with large resources and long experience. Moreover, there may be other, smaller oxygen users in your area. An Airco off-site plant built primarily to supply you would be designed to meet the area requirements, thereby making a lower unit price possible.

Multi-Plant Back-Up: At all times, you are assured of a steady flow of oxygen because your new plant is a part of Airco's integrated system of supply — a nationwide network of oxygen plants.

New Processes Using Oxygen and Nitrogen

Many plants under construction are designed for processes based on tonnage oxygen: partial oxidation of natural gas or fuel oil to produce hydrogen for ammonia and methanol; ethylene oxidation processes; Sachsse acetylene process; oxidation of select hydrocarbons to aldehydes, acids and alcohols. Tonnage nitrogen from such plants is being used increasingly for ammonia synthesis and as a blanketing medium to provide an inert atmosphere.

Whatever oxygen- or nitrogen-using process you are considering, it will pay you to investigate Airco's tonnage products. For complete details, contact Airco.

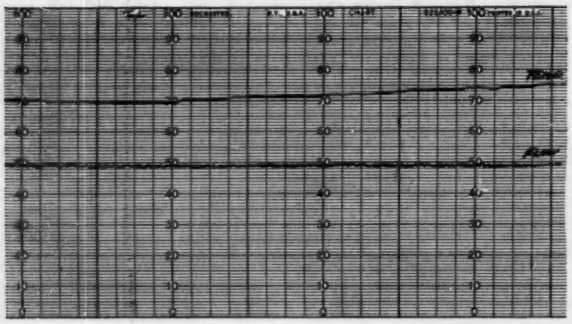
AIRCO **AIR REDUCTION SALES COMPANY**

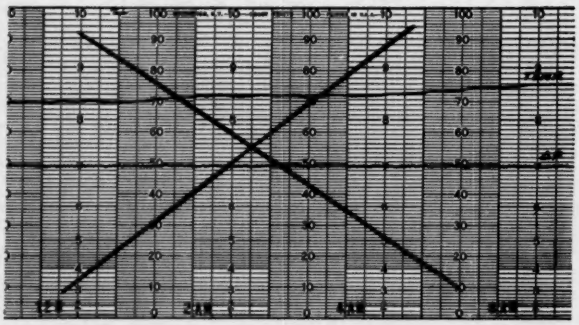
A DIVISION OF AIR REDUCTION COMPANY, INCORPORATED, 150 EAST 42ND STREET, NEW YORK 17, N. Y.
REPRESENTED ON THE WEST COAST BY AIR REDUCTION PACIFIC COMPANY

NEW FROM

212T TRANSCOPE® Indicating
Flow and DP Transmitter

Now . . . calibration linear with flow obsoletes sectionalized charts





SPECIFICATIONS

Range Interval: *continuously adjustable 20" to 250" w.g.*

Accuracy of Calibration: (*Referred to input*)—*Transmitter ½%.*

Static Rating: *1500 psi.*

Overrange: *Can accept full static pressure overrange, reverse or direct.*

Case: *Sturdy, die-cast aluminum, for field mounting.*

Primary Materials: *Carbon steel or Type 316 S.S. Flanges and adaptors with Type 316 S.S. trim.*

Taylor Instruments

Taylor

The only DP transmitter that can be calibrated for output linear* with flow as well as differential pressure without changing parts

Really a "transmitter with a built-in computer", the No. 212T TRANSCOPE Force-Balance Flow and Differential Pressure Transmitter can be converted from linear with flow to linear with differential pressure (liquid level) simply by calibration. It employs a liquid-filled, diaphragm sealed primary unit and a unique secondary unit in which force balance is accomplished by a powerful motion servo and spring combination. Servo power makes possible these features, unavailable in conventional transmitters:

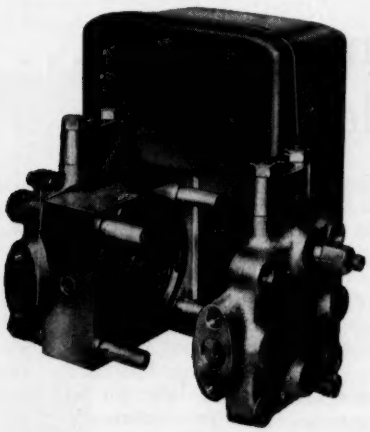
- Ratio and cascade control without intermediate, separate square root extraction.
- Simple analog computations involving flow and other variables pneumatically without an extra "black box".
- Elimination of the need for sectionalized charts.
- Indication at the process on a big 11¾" scale, visible up to 35 ft. away.

This ingeniously designed transmitter may be Calibrated Linear with Differential Pressure or Calibrated Linear with Flow, and can be either indicating or non-indicating. For computer control, for example, linearized flow is a logical short cut.

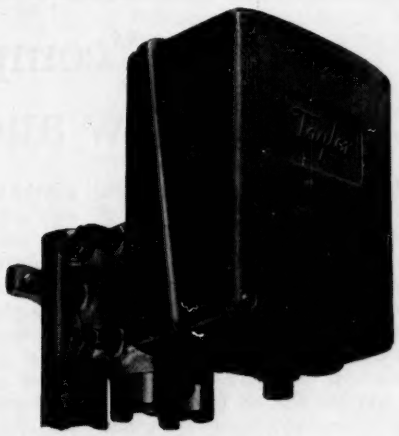
Use of a liquid-filled primary gives positive overrange protection. Working parts in the primary are exposed only to the filling liquid—not to the process. Static pressure compensation is inherent in the unique thrust pivot of the force beam. Connections are extremely convenient. Mounting facilities are more adaptable than ever before.

With all its outstanding features you pay no premium for the 212T Transmitter. Ask your Taylor Field Engineer for a demonstration, or write for **Bulletin 98413.** Taylor Instrument Companies, Rochester, N. Y., and Toronto, Ontario.

**Even without this unique feature, the 212T would still be a superior DP transmitter.*



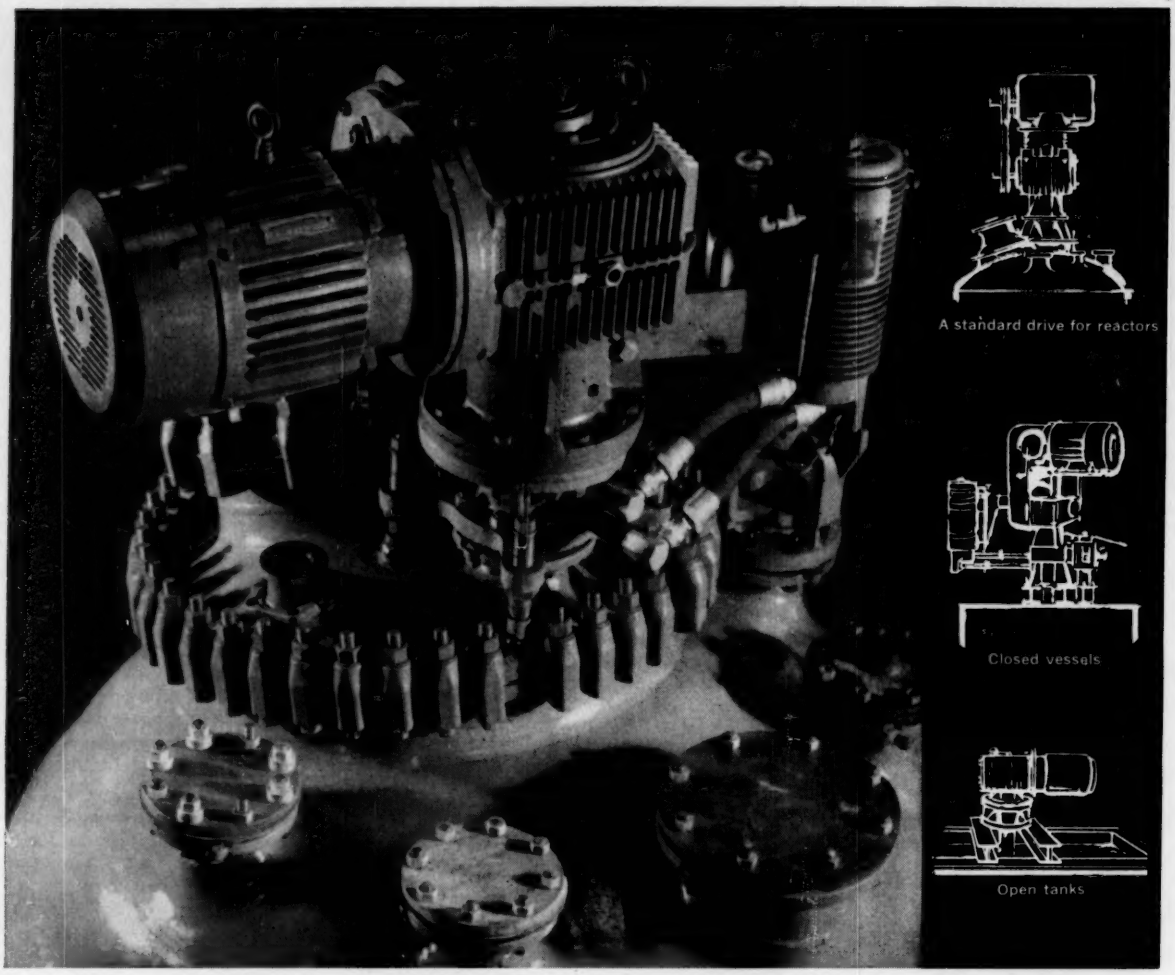
Convenient through-bolted flanges for easy servicing. Process connections top, bottom or side.



213T non-indicating model shows rear mounting and bottom process connections.

MEAN ACCURACY FIRST

FLUIDICS* AT WORK



It's a "compact" from Pfaudler . . . the new and versatile TW Drive

One look. That's all it takes to show you that this new Pfaudler® TW Drive truly deserves to be called a "compact."

The model pictured is the 7½ HP, Fixed Speed Gear, 5TW, mounted on a Pfaudler Glasteel reactor. Note how the compact, integral assembly serves as both drive support and housing for seal or stuffing box.

Note, too, the absence of bulky supports or other obstructions. Thus, lots of head room and easy access to top-head openings.

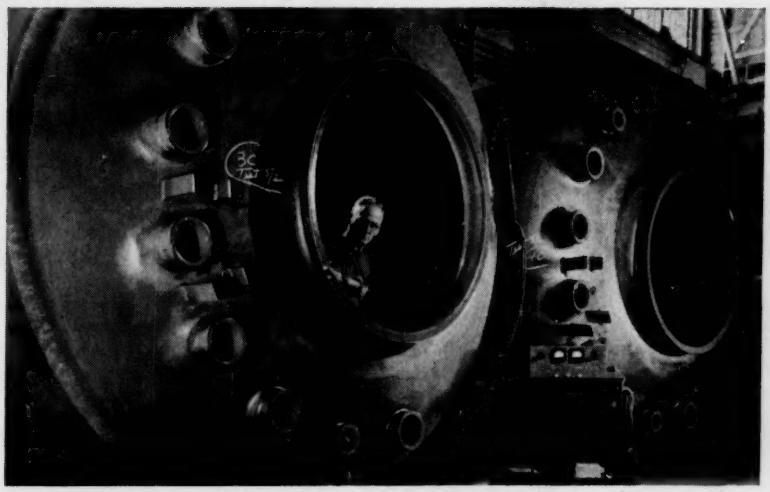
Versatile. Though it's small in size compared with many types of drives, the TW series can solve a variety of your agitation problems. You can use a TW on glassed steel or stainless steel reactors and on many of the agitated vessels in your plant. Open vessels need only a bridge for support. Closed vessels call for a standard nozzle with commercial pipe flange, plus support bosses.

Wide choice. Name the type of drive best suited to your application—fixed-speed gear, fixed-speed belt, variable-speed belt, variable-speed hydraulic. The TW is available in all of these types, in a complete range of agitator speeds and horsepower capacities.

It's a wise choice for your *standard* plant drive.

Common to all TW's, along with compactness are the following: (1) Maximum power for space and weight—because both worm and gear of speed reducer are throated for a larger contact area, (2) Quiet operation—since the large area of tooth contact assures accurate meshing and eliminates distortion, (3) Minimized agitator deflection—because where bending moment is greatest a large shaft diameter has been provided, (4) Long service life for seal and stuffing box parts. Housing serves as an integral part of the drive, so variations in deflection between component parts are minimized.

Summing up. The new "compact" TW Drive is one of a complete line of Pfaudler drives that offers economical, efficient answers to many of your agitation problems. Details are included in Bulletin 1001. For your copy, write to the address indicated on the facing page.



Glasteel reactors guaranteed full year against corrosion

This man is electric testing the interior of a Glasteel reactor. He's making sure that the product-contact surface is completely covered with corrosion-resistant Pfaudler glass.

That's the *glass* in Glasteel. The *steel* is outside, for working strength. Fusing the two together gives you a combination that lets you forget—not fight—corrosion.

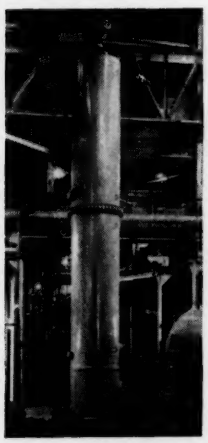
You can use Glasteel safely with all solutions of all acids except HF to 212° F (even up to 450° F for certain acid solutions, depending on concentration) and with many alkalies at moderate temperatures.

And you can do so confidently because Pfaudler Glasteel equipment is guaranteed against corrosion for a full year after shipment, when used under operating conditions specified and approved. If rendered unusable by chemical attack during this period, Pfaudler will repair or replace it, fob, factory.

Glasteel is also inert; it won't influence quality, flavor, color or purity of your products. And its smooth, abrasion-resistant surface resists build-up. So heat transfer is not impeded and cleaning is both quick and complete.

Standard Glasteel reactors are available with capacities from 5 to 4,000 gallons. Custom designs go to 10,000 gallons and larger. You can also get a variety of other process equipment made of Glasteel.

For details on reactors, ask for Bulletin 988. To bring your files up to date on *Glasteel*, it's Bulletin 985. Write to the address below.



Can you use a 32-foot-high, agitated, Glasteel polymerizer?

This one was recently installed in a leading U. S. petroleum refinery. It will be used in producing polyethylene resin. We made it to the customer's specifications.

We also made the two-piece Glasteel agitator that's approximately 24 feet in length. The agitator sections are joined by carbon steel flanges, protected from corrosive attack by a Hastelloy shroud sealed with Teflon packing. Despite the unusual length, the agitator has no step bearing.

We commend this vessel to your attention for two reasons: It shows how we combine materials for optimum performance. And, equally important, it's a good example of the BIG process equipment Pfaudler makes to meet your special needs. Your inquiries are invited.

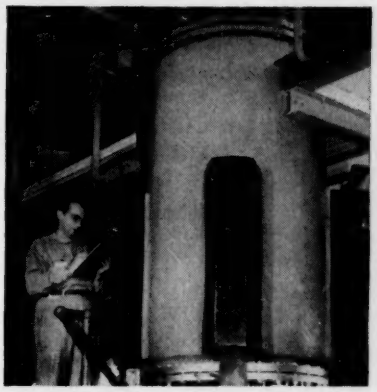
How tantalum helped Hoffmann-LaRoche scale up production

Here's the problem: You're making a relatively new drug, using a process that requires holding a mixture of phosphoric and hydrochloric acids at 385° F for several days.

You've been turning it out on a pilot-plant basis, using flasks. Market conditions require that you get into full-scale production. How?

The nature of the corrosive reaction narrows your choice to three materials: tantalum, gold, and platinum.

That's the situation Hoffmann-LaRoche Inc., Nutley, New Jersey, was up against recently. The practical answer: a 275-gallon, tantalum-lined reactor made by Pfaudler.



We say practical because tantalum is essentially inert and does not combine with the process ingredients to cause contamination. Practical because tantalum resists most acids, even at elevated temperatures. Practical because a .020" tantalum liner in a 5/16" carbon steel shell is reasonably priced.

And, finally, practical because Pfaudler brings to the fabrication of such equipment a wealth of experience and capability. We can and do work with tantalum, titanium and zirconium, so that you can look to these metals to solve your corrosion problems.

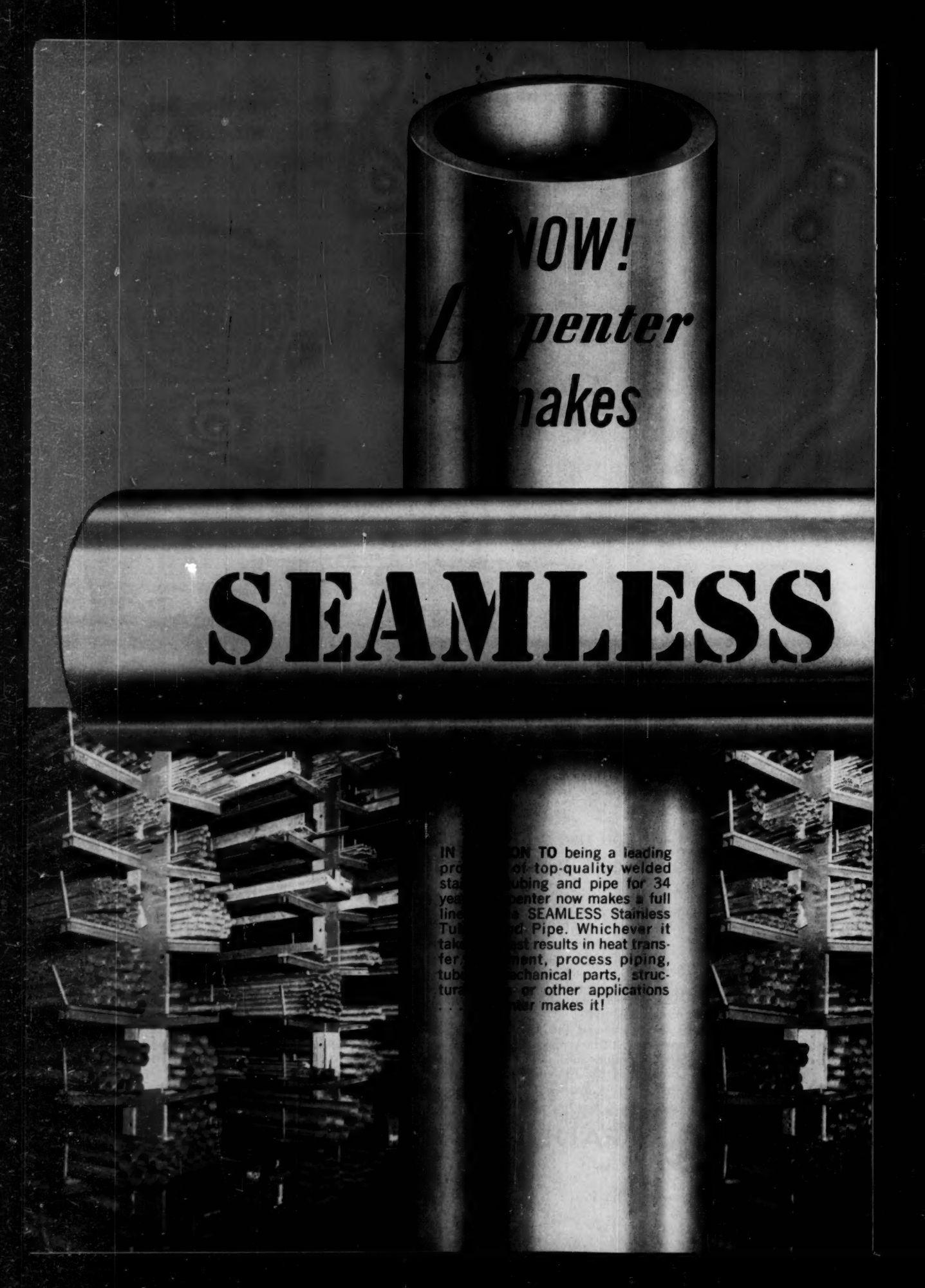
More facts? Bulletin 978 summarizes our activities in the "refractory" metals. We'd be happy to send you a copy.

Address all inquiries to: Pfaudler Division, Department CE-61, Rochester 3, New York.

*FLUIDICS is the Pfaudler Permutit program that integrates knowledge, equipment and experience in solving problems involving fluids.

PFAUDLER PERMUTIT INC.

Specialists in FLUIDICS . . . the science of fluid processes



IN ON TO being a leading pro of top-quality welded sta ubing and pipe for 34 yea penter now makes a full line SEAMLESS Stainless Tu d Pipe. Whichever it tak st results in heat trans- fer nent, process piping, tub chanical parts, struc- tura or other applications . . . ter makes it!

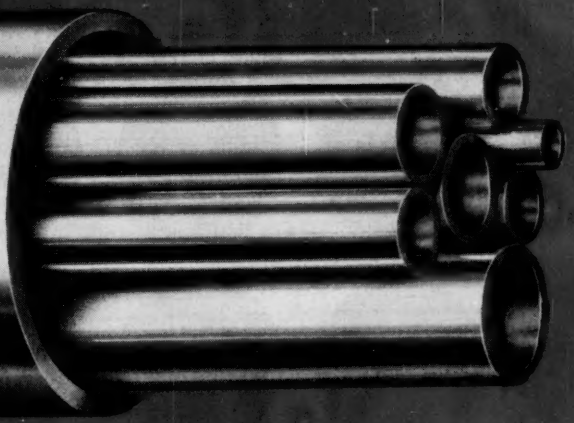
Made by best extrusion process

Carpenter SEAMLESS Stainless Tubing and Pipe are made with the accent on quality and uniformity at every stage of manufacture from raw materials to finished products. They are initially hot-formed by the highly perfected Ugine-Sejournet patented extrusion process. Stainless alloys for making these new products are produced in Carpenter's own specialty steel mill to closely balanced analyses. Extremely uniform structure and utmost freedom from internal flaws due to segregation and center line weakness are assured in these stainless steels by Carpenter's exclusive MEL-TROL® process. Cold finishing of all Carpenter SEAMLESS Stainless Tubing and Pipe assures extremely close accuracy of O.D. and I.D. dimensions, excellent physical properties and super-smooth surface finishes. Optimum corrosion resistance and working properties are made certain by careful annealing, pickling and passivating under strict quality control. Final tests and inspections insure that the finished SEAMLESS stainless products will always be "as ordered" and capable of giving the dependable, cost-saving service expected of them. Quality is a tradition with Carpenter!

Wide range of types and sizes

Carpenter makes SEAMLESS Stainless Tubing and Pipe in a full range of standard analyses, including Carpenter Stainless No. 20Cb. Tubing Sizes range from ¼" through 6½" O.D. with wall thicknesses of .004" to .864". Pipe Sizes are ⅛" to 6" in Schedules 5, 10, 40, 80, 120, 160 and Double Extra Heavy. Surface Finishes ranging from as-drawn to 320-grit polish can be provided on the I.D. and/or O.D. as required. Tubing of all types and sizes is regularly furnished in lengths up to 45 feet. Longer lengths are available within certain specifications. Carpenter SEAMLESS Stainless Tubing and Pipe can be supplied to meet ASTM, AMS and Government Specifications and also to meet individual users' special requirements. This new Carpenter service on SEAMLESS stainless tubing includes various shapes other than round, integral-finned tubes and bi-metallic tubes of various ferrous and non-ferrous combinations. The right answers to a wide variety of corrosion and high temperature problems in heat transfer equipment, process piping systems and hollow mechanical parts are provided by the broad range of SEAMLESS Stainless Tubing and Pipe available from Carpenter.

STAINLESS TUBING & PIPE



Available from stocks!

Popular types and sizes of Carpenter SEAMLESS Stainless Tubing and Pipe, including Heat Exchanger Tubes, can be shipped promptly from large warehouse stocks in principal U. S. cities. Large or small orders can be cut to exact specified lengths. Orders for non-stocked types and sizes will get best mill delivery available anywhere. Call or write your nearest Carpenter Representative, Warehouse or Distributor for up-to-date Stock List.

"One call does it all"

As a producer of both seamless and welded stainless tubing and pipe, Carpenter offers an unusually broad scope of impartial service on these products: Nation-wide availability from stocks; experienced assistance with matching stainless pipe and tubing to job conditions for best all-around results; technical help in solving corrosion, high temperature, fabrication and other problems; recommendations for improving the cost-life ratio of existing stainless pipe and tubing applications; dependable mill performance on special requirements. A new Selecting and Buying Guide, Bulletin 128, on Carpenter Stainless Pipe and Tubing —Seamless and Welded—is available on request to The Carpenter Steel Company, Alloy Tube Division, Union, N. J.

selection geared to service

Carpenter steel

The Carpenter Steel Company, Main Office and Mills, Reading, Pa.
Export Dept., Port Washington, N. Y.—"CARSTEELCO"
Alloy Tube Division, Union, N. J.
Webb Wire Division, New Brunswick, N. J.
Carpenter Steel of New England, Inc., Bridgeport, Conn.

NOW OPTIMUM INTERCHANGEABILITY IN CHEMICAL PROCESS PUMPS

Simplify process engineering . . . cut parts inventories with this one basic design!

Pinched for process design time? Bugged by corrosive, pressure and temperature problems with pumps?

Solve all these, and other modern pumping problems with this new concept in pump design. It's a back pull-out, horizontal, single-stage, end suction centrifugal. The Model 3195 makes process engineering easier . . . keeps pumping cost low because it gives you:

Maximum interchangeability. The Model 3195 gives you the greatest range of coverage and flexibility—with minimum parts needed—of any line on the market.

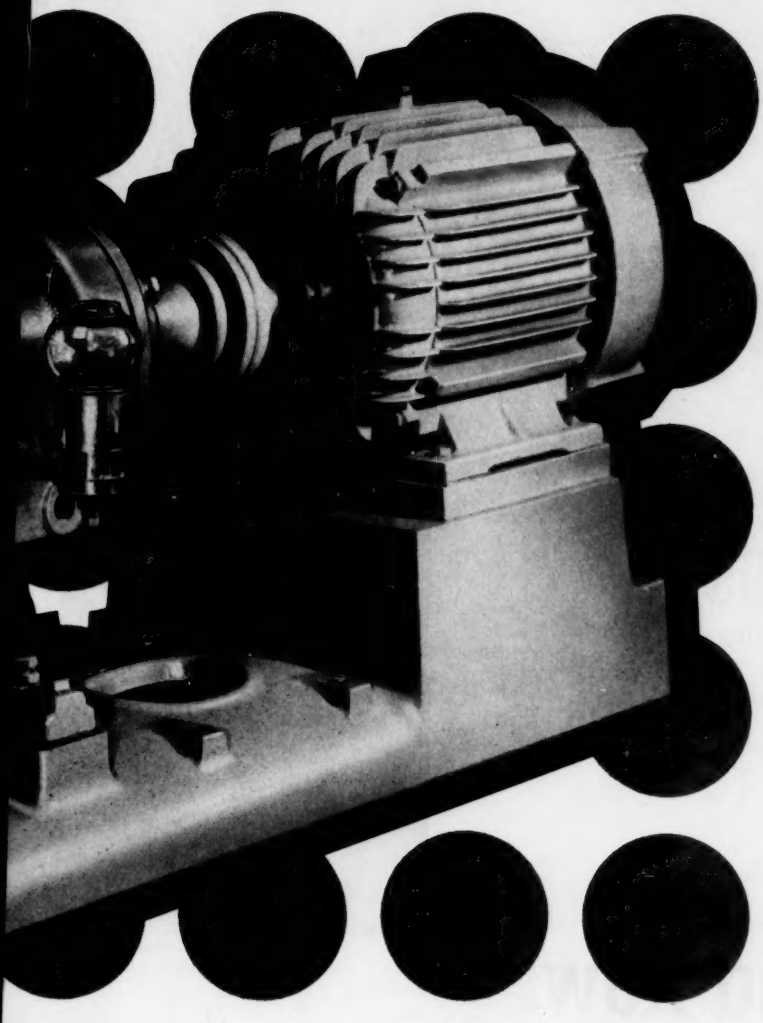
For example, you can mount any one of the 11 pump ends to any one of three bearing frames (shafts 1¼, 1¾, and 2⅛ through stuffing box). Service conditions will determine your choice of bearing frame.

Nominal impeller diameters of 6″, 8″, and 11″ cover the range of the Model 3195 line.

The diagram at right shows you dimensional interchangeability of the units themselves.

Easier maintenance. Back pull-out design, one of a number of easier maintenance features, lets your men replace parts without disturbing piping connections or motor mounting.

Mechanical reliability. Shaft deflection less than .002″ at stuffing box face. Two-year minimum bear-

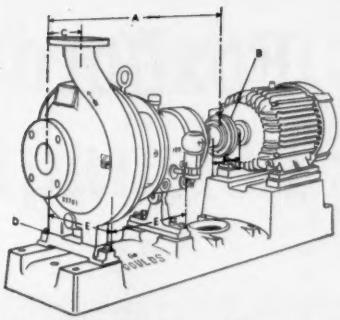


ing life. Dowelled construction provides exact parts alignment.

Full-range coverage.

Capacities . . . . . 5 to 775 GPM
Head . . . . . 10 to 300 ft. TDH
Temperature . . −350° to +500° F
Working Pressure
0 PSIA to 275 PSIG

Cost-conscious materials. You can get any pump in the line **off the shelf** in any of these standard constructions: ductile iron, 316 stainless steel, Gould-A-Loy 20. It is also available in any machinable alloy.



Dimensional Interchangeability Between All Model 3195 Pumps

A One over-all length in all sizes . . 23"
B One coupling fit for all sizes . . . 1⅛"
C One dimension end of suction to centerline of discharge . . . . . 4"
D One bolt size for holding pumps to bases . . . . . ½"
E One bolt spacing for holding all pumps to bases
F One spacer coupling length for all sizes . . . . . 3½"

GOULDS PUMPS

GOULDS PUMPS, INC.
Dept. CE-61,
Seneca Falls, New York

Please send me bulletin on Goulds Model 3195 Chemical Process Pump, showing interchangeability, dimensions and curves.

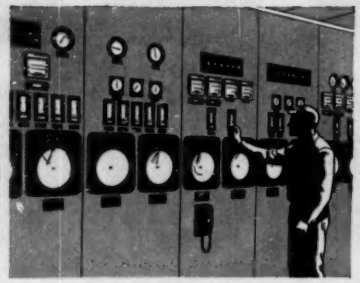
Name.....

Company.....

Street.....

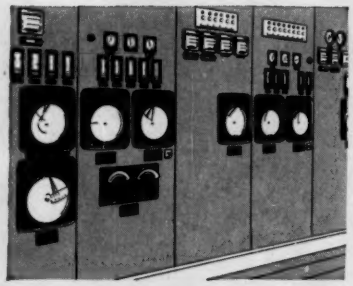
City.....Zone.....

County.....State.....



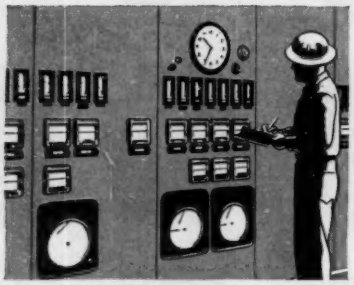
1951

Foxboro Consotrols
selected for new Celanese plant in Pampa, Texas



1952

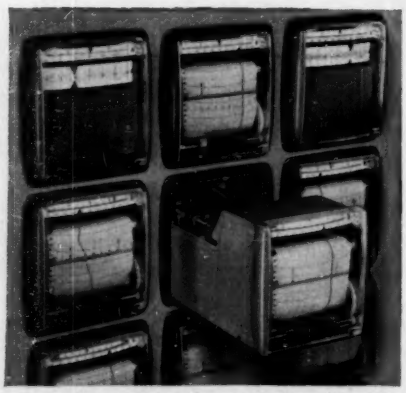
Foxboro Consotrols
selected for new Celanese special products and vinyl acetate units at Pampa



1957

Foxboro Consotrols
selected for new Celanese acrylate unit at Pampa.

. . . and now Foxboro Consotrols* major new

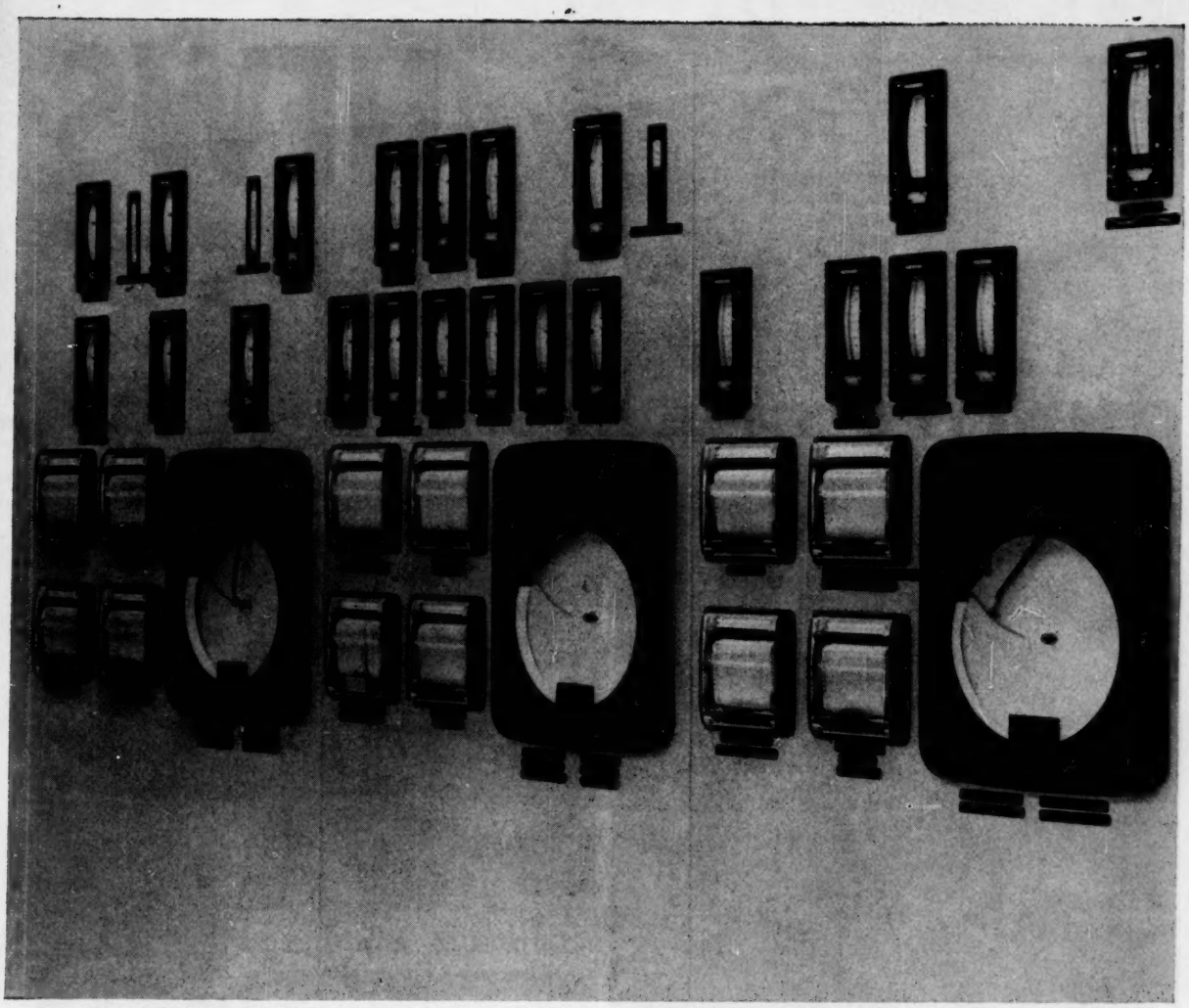


Foxboro M/54-58 Consotrol Recorder-Controllers feature full-scale 4-inch vertical-travel chart; ready adaptability to changes in processing requirements. Instruments mount on 7-inch centers for minimum panel size. Unique "floating disc" M/58 Controller has unmatched stability, sensitivity, and reliability.

Thirty million pounds of acrylates a year is the capacity of the newly-expanded petrochemical plant of Celanese Chemical Company, Pampa, Texas.

Foxboro Pneumatic Consotrol Instruments have been the nerve centers of the entire plant since the first panel was installed in 1951. Why the continued preference? M. A. Gann, Instrument Supervisor, puts it this way:

"We have over a thousand instruments in this plant. Accuracy,



Newest Foxboro Panel, designed and built by Foxboro for Celanese Chemical's Pampa, Texas plant, controls processing in new Higher Acrylates Unit. Foxboro flow, temperature, and pressure transmitters are also used exclusively.

are selected again for Celanese expansion at Pampa!

reliability, and low maintenance are absolute musts, and we've found that Foxboro Consotrols consistently deliver on all counts."

Foxboro's M/54-58 Recorders-Controllers, for example, provide repeatability of ±0.1%, complete "pull-out" convenience, and the most stable control action of any instrument in the field.

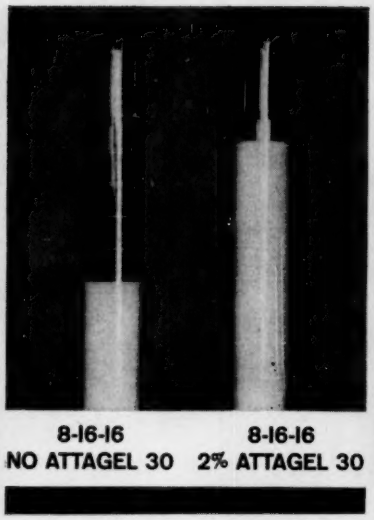
Write for Bulletins 13-18 and 13-19. Get the whole story on Consotrols. See what they can do for *you*. The Foxboro Company, 366 Neponset Ave., Foxboro, Massachusetts.

FOXBORO
REG. U.S. PAT. OFF.

*Reg. U.S. Pat. Off.

NEWS BRIEFS

ON THE CREATIVE USE OF



Typical high analysis possibility with Attagel 30...8/16/16 on furnace grade phosphoric acid. Similar results are possible with wet process acid.

High Analysis Liquid Fertilizers possible when stabilized with Attagel 30

Analysis limits in liquid fertilizers have been raised by the addition of Attagel 30 without troublesome settling-out problems. Higher amounts of trace elements, insecticide and herbicide salts and various other ingredients can also be added.

By adding only 1 to 3 percent Attagel 30 to the liquid, you can have a stable, pourable suspension which will retain its stability. Rich liquid fertilizers are then possible even where solubility has been a heretofore unsurmountable problem. For more information on its many uses, send the coupon.

Minerals & Chemicals Philipp

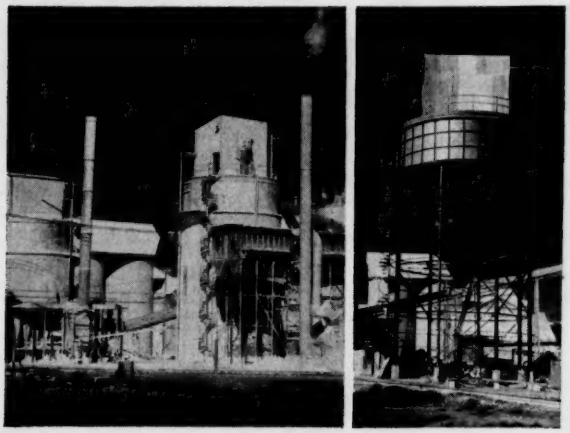
8849 Essex Turnpike, Menlo Park, New Jersey

EXPORT DEPT.: Room 150, Garden State Parkway, Menlo Park, N. J. (Cable Address: 'MICOR')

ASP's... inexpensive products of many abilities

MCP aluminum silicate pigments (ASP's) are mineral products of controlled fine particle size which meet exacting standards as to freedom from contaminants such as moisture, sand, mica, and water soluble salts. Inert and insoluble under normal use conditions, they are applicable as extenders, blocking agents, fillers, and for other uses. Worth looking into for your product . . . just send the coupon.

MCP PROCESS MATERIALS



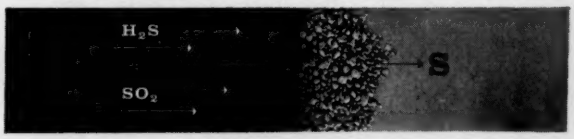
Spray Dried Coating Clay

capacity increased as MCP adds fourth unit

Kaolins that are spray dried during processing have a fine spherical bead that contains less than 1% moisture, flow readily, do not cake, and are easily fluidized.

MCP technologists were first (1947) to spray dry Kaolins used in the coating of paper. These high-purity, high-uniformity Kaolins have been so much in demand that three more spray dryers have been added in the last seven years. The latest, completed in 1961, gives MCP twice the number of spray-drying units as compared with any other clay producer.

With four such units, MCP offers a broad range of spray dried Kaolins to meet individual customer needs. Since all four are completely instrumented, MCP Kaolins are meticulously quality controlled, uniform in analysis, consistently easy to handle. They are applicable to other uses too . . . for more about them, send the coupon.



Sulfur Recovery Catalyst — Porocel

has enviable record in petroleum field

Petroleum refinery gases carry a large amount of combined sulfur. Since 1944 much of this sulfur has been recovered through the application of the Claus system of partial combustion of H_2S and a catalyst-promoted reaction of sulfur dioxide and hydrogen sulfide. MCP's catalyst, Porocel, has been identified with virtually all of the installations because of its excellent recovery performance— 92 to 97%, in purity of 99.97%.

Porocel is a thermally-resistant, high-grade bauxite. It is used in the petroleum industry for decolorization, adsorption, drying, brightening, defluorination, and other purposes. It has an excellent cycle life, long process life. For more information use the coupon.

MINERALS & CHEMICALS PHILIPP CORP.
8849 Essex Turnpike, Menlo Park, N. J.

I am interested in:

☐ Edgar Paper Clays ☐ Attagel 30
☐ ASP's ☐ Porocel Catalyst

Please send without obligation:

☐ data ☐ samples ☐ prices ☐ technical representative

Name _____
Title _____
Company _____
Address _____
City _____ Zone _____ State _____

Use this quick two-check coupon . . .

✔ for your product interest
✔ for what you need to get tests started

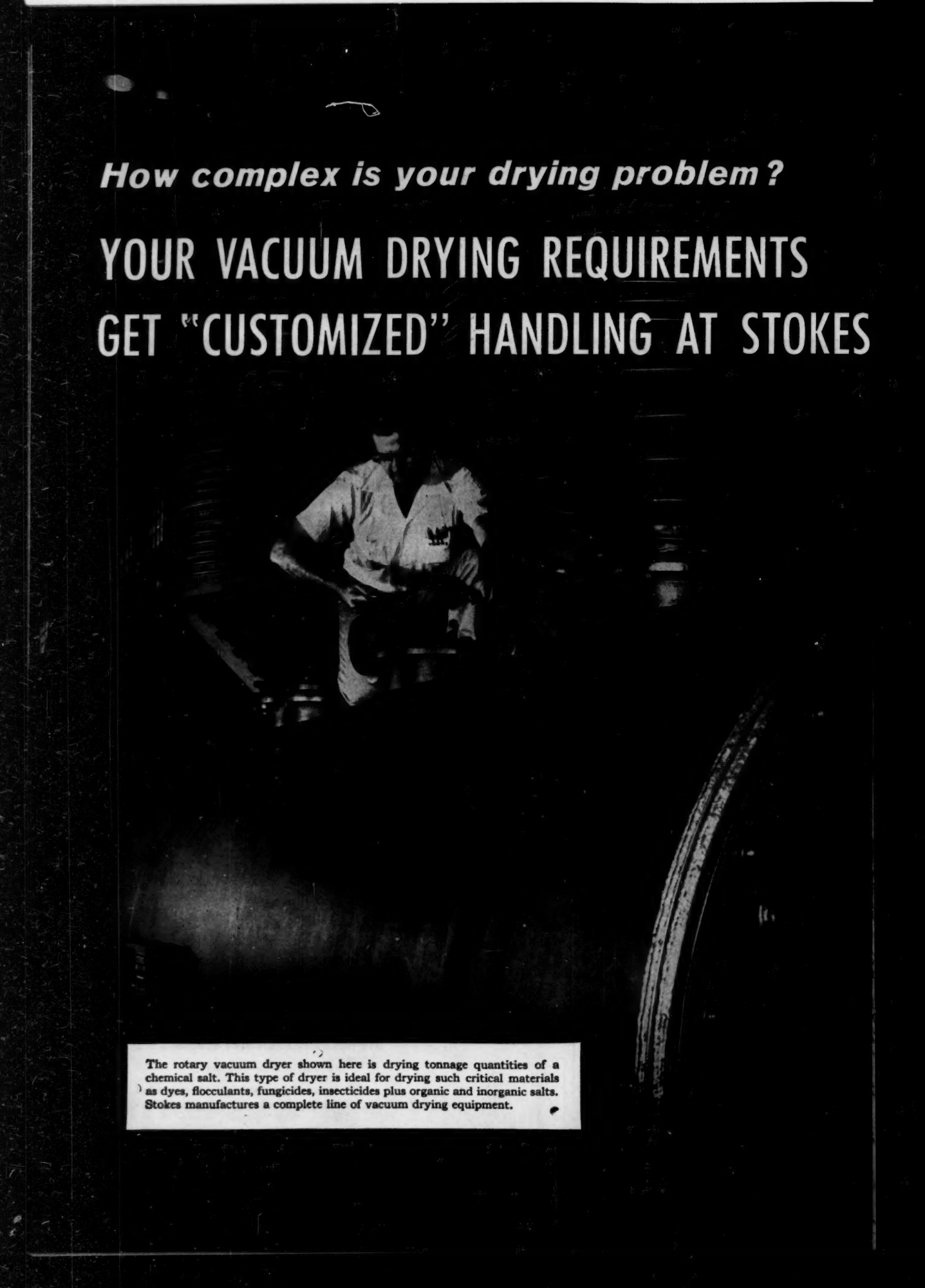
we'll fill your requests immediately

CORPORATION

For more data, see your 1961 Chemical Materials Catalogue, pages 423-430

How complex is your drying problem?

YOUR VACUUM DRYING REQUIREMENTS GET "CUSTOMIZED" HANDLING AT STOKES



The rotary vacuum dryer shown here is drying tonnage quantities of a chemical salt. This type of dryer is ideal for drying such critical materials as dyes, flocculants, fungicides, insecticides plus organic and inorganic salts. Stokes manufactures a complete line of vacuum drying equipment.

Conical Vacuum Dryer shown below in Stokes laboratory is being used for a variety of tests on customer products.

PROCESSING tonnage quantities of materials in an inadequate vacuum dryer can be time consuming and costly. That's why Stokes experienced vacuum engineers study each drying requirement individually . . . then design the drying system to meet your specific needs. Drying systems in capacities from a few pounds to several tons are available . . . along with application engineering, laboratory service and pilot plant operations. Stokes puts its 50 years of vacuum processing experience to work on every drying problem . . . bringing you both money-saving and quality results. What's more, Stokes manufactures all its own pumps and accessories to assure you one-manufacturer responsibility in addition to unparalleled vacuum know-how.

Stokes will thoroughly explore your production problems . . . make recommendations on the basis of a practical knowledge of process operations . . . and confirm the recommended equipment by actual pilot plant production in the Stokes laboratory, if necessary.

WRITE FOR HANDY GUIDE

New booklet gives important hints on vacuum dryer selection. It describes briefly shelf, cone and rotary dryers . . . their construction, their operation and different types of applications. Our representative in your area will be glad to discuss your drying problems with you and make detailed recommendations. Check CEC for his address and telephone number.

STOKES

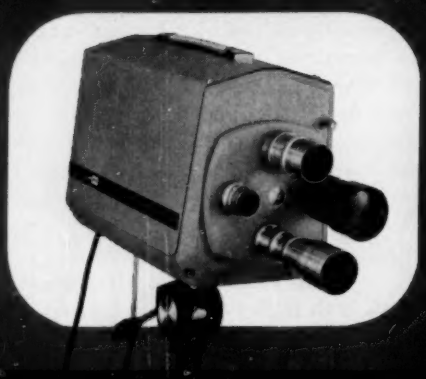
Processing Equipment Division

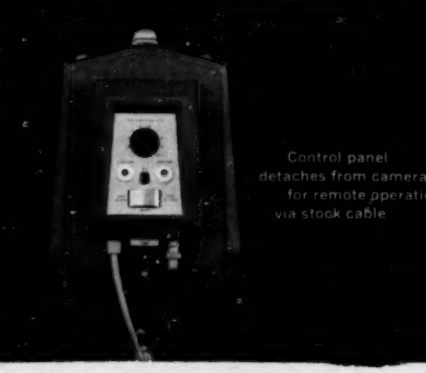
F. J. STOKES CORPORATION

5500 Tabor Road, Philadelphia 20, Pa.

STOKES INTERNATIONAL: PHILADELPHIA • TORONTO • LONDON

new! low-cost self-contained TV camera provides 650 line resolution!





Control panel detaches from camera for remote operation via stock cable

High-quality closed circuit television is now more practical than ever. KIN TEL's new 20/20 camera is the reason. It contains its own control circuits. This eliminates the separate unit so long traditional with high-quality TV systems... lets you connect the camera directly to a monitor–or home TV receiver.

The 20/20 is easier and less expensive to install, operate, service. Yet it gives the sharpest, clearest pictures in the industry – 650 lines of horizontal resolution. It is so sensitive that you can get usable pictures with as little as one foot candle of illumination–less than the light now falling on this page.

Trouble-free operation is designed into the 20/20. Transistor circuits are used wherever possible. Power consumption is only 25 watts. Protective circuits prevent vidicon damage in case of sweep failure. And the swing-out circuit boards make servicing easy.

Many standard accessories custom-fit the 20/20 to your exact needs. A light compensation circuit automatically adjusts the camera for light variations as great as 4000:1. Motors provide remote control of the lens turret, lens focus, and a lens-speed filter. Sync generators assure 2:1 interlace either in the standard industry-wide sweep/scan pattern, or in the FINELINE pattern that gives you greatly increased vertical resolution. RF modulators make the pictures available on standard TV channels 2 through 6.

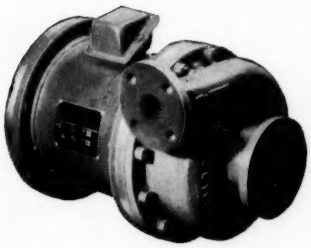
Cut costs, reduce errors with one of KIN TEL'S complete lines of high-quality, closed circuit TV. Other companies do. U. S. Steel uses KIN TEL TV to see inside open-hearth furnaces. E. F. Hutton uses one to transmit stock quotations. Los Angeles Department of Water and Power uses KIN TEL TV to check steam plant burners and to view remote water-level meters. The San Francisco Naval Shipyard uses one to guard against pilferage. American Potash & Chemical conveyor lines and warehousing operations are monitored by KIN TEL TV as are radiation studies at General Atomic. The U.S. Air Force uses KIN TEL TV for detailed surveillance of every operational ICBM outside the Iron Curtain. All told, hundreds of KIN TEL TV systems are performing critical and routine jobs safely, inexpensively, tirelessly.

Application help is free for the asking. At no obligation, KIN TEL field engineers will determine whether a TV system can be put to profitable use in your application. Just write direct for catalog 6-203 and the name of your closest KIN TEL representative.

5725 Kearny Villa Road
San Diego 11, California
BRowning 7-6700

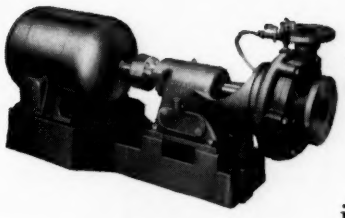
KIN TEL
A DIVISION OF
COHU
ELECTRONICS, INC.

DON'T LET CORROSIVES CREATE A PUMPING PROBLEM



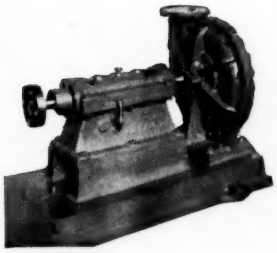
HERMETIC PUMPS

. . . a new design for use where leakage would be costly or dangerous. They will not leak! Wear compensating bearings take up thrust loadings. Available in a variety of materials of construction. For pressures up to 400 psi.



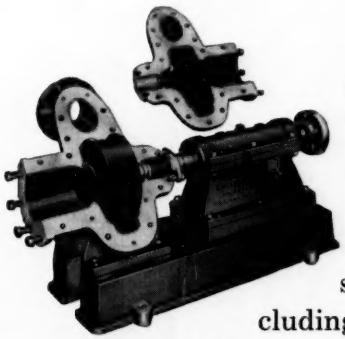
SPECIAL ALLOY PUMPS

. . . of single-suction ball bearing type, capable of handling your toughest liquid moving job. Materials of construction include Hastelloy B or C, nickel, bronze, lead, stainless, just about any material that can be cast and machined. Capacities to 1100 gpm, head to 360′.



HARD LEAD PUMPS

. . . with vertical split housing. All components exposed to liquid are of hard lead. Typical 'Buffalo' heavy-duty construction throughout. Built in capacities to 600 gpm, heads to 120′. Details available on request.



RUBBER LINED PUMPS

. . . offered with various types of rubber from soft to hard, including neoprene with high graphite content. Diagonal split housing for ease of maintenance. Piping need not be removed for inspection of rotating parts. Single and double suction models.

For more detailed information on 'Buffalo' pumps for industry, contact your resident Buffalo Engineering Representative or write direct.

"Buffalo" PUMPS

BUFFALO PUMPS DIVISION

BUFFALO FORGE COMPANY

Buffalo, New York

Canada Pumps Ltd., Kitchener, Ontario

'Buffalo' Air Handling Equipment to move, heat, cool, dehumidify and clean air and other gases.

'Buffalo' Centrifugal Pumps to handle most liquids and slurries under a variety of conditions.

'Buffalo' Machine Tools to drill, punch, shear, bend, slit, notch and cope for production or plant maintenance.

Squier Machinery to process sugar cane, coffee and rice. Special processing machinery for chemicals.

What's News in Rubber...

ENJAY BUTYL HT 10-66 gives this playground mat the ability to withstand years of scuffing and abrasion, repeated impacts and flexing, as well as outdoor weathering.

A NEW RUBBER TO DO THE HARD JOBS!

ENJAY BUTYL HT 10-66

Halogenated for...high heat resistance...covulcanization with other elastomers... low compression set... and faster cures

Plus these well-known Butyl advantages:

- *High flex, tear and abrasion resistance*
- *Low gas and moisture permeability*
- *Excellent chemical resistance*
- *High weather and ozone resistance*

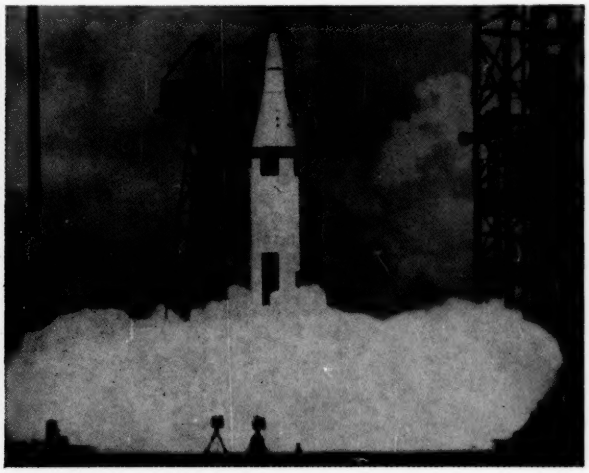
NOW AVAILABLE IN A VARIETY OF MOLECULAR WEIGHTS

AIR-HOLDING INNERLINERS of Enjay Butyl HT 10-66 help assure correct inflation pressure for tubeless tires and can give greater blowout protection as well as improved tire-tread wear. Other tire uses include white sidewalls, black sidewall veneers and chafer strips.

APPLIANCE PARTS of Enjay Butyl HT 10-66 withstand the deteriorating effects of detergents and dishwashing compounds. Absorption of hot water by the rubber is reduced to a minimum.

HOT MATERIAL BELTS like this perform well at continuous temperatures of 350°F, thanks to the exceptional heat aging properties of Enjay Butyl HT 10-66.

SHOCK-RESISTANT LAUNCHING PADS of metal-covered Enjay Butyl HT 10-66 withstand launching shock and exposure to intense heat encountered in missile firings.



WRITE TODAY FOR NEW TECHNICAL MANUAL HT 10-66...

Contains processing information, performance data and recommended cure systems. For your free copy or for technical assistance in applying this important new polymer, write to Enjay, 15 West 51st St., New York 19, N. Y.

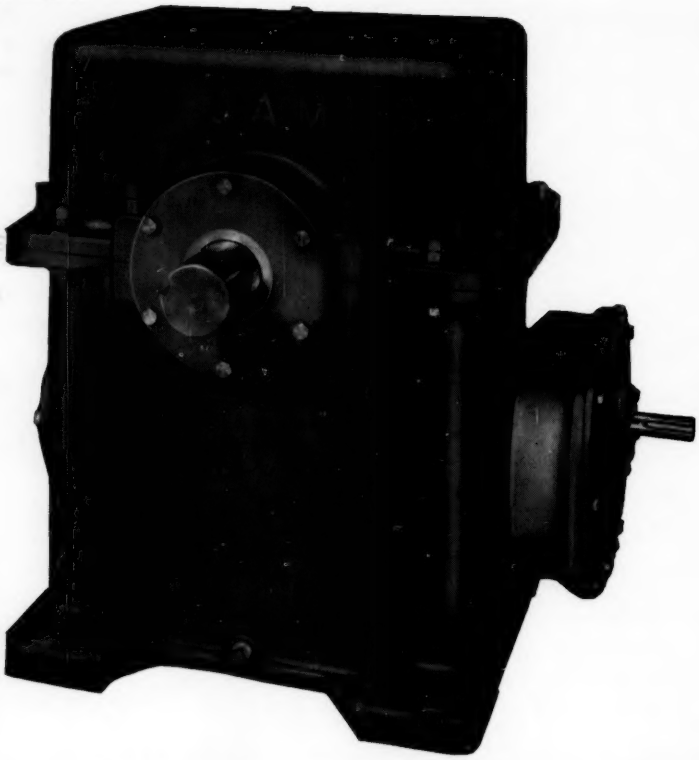
EXCITING NEW PRODUCTS THROUGH PETRO-CHEMISTRY

ENJAY CHEMICAL COMPANY

A DIVISION OF HUMBLE OIL & REFINING COMPANY

ENJAY® BUTYL

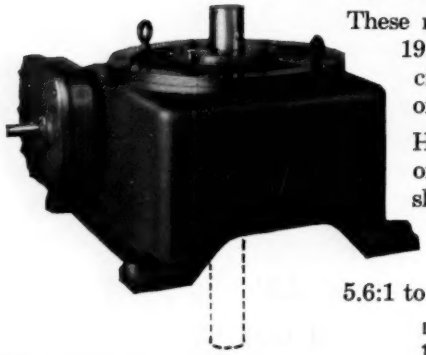
D. O. JAMES SPEED REDUCER REDUCTION DATA



for high efficiency

at higher reduction ratios, use helical worm reducers

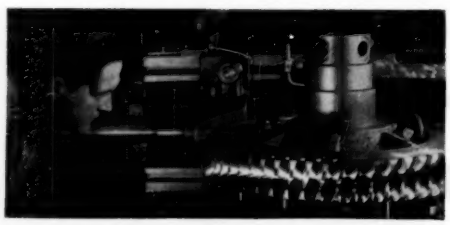
D. O. James helical worm gear speed reducers include a conventional worm and gear plus an auxiliary set of high-efficiency helical gears on the input shaft.



These reducers are built in 13 sizes, .13 to 150.0 hp, 19.2:1 to 400:1 ratios. At ratios above 60:1, efficiencies range as much as 15% higher than those of straight worm reducers.

Horizontal-drive types are available with right- or left-hand assembly, vertical types with the slow-speed shaft extending upward or downward.

For complete data on these and other types of worm gear reducers from .04 to 206 hp, 5.6:1 to 10,000:1 ratios, ask for Catalog No. 45-D.



D. O. JAMES GEAR MANUFACTURING CO.
1140 West Monroe Street, Chicago 7, Illinois
Since 1888, every type of gear and gear speed reducer

D.O.James

...where you always get good gearing

WORLD RECORD IN ETHYLENE!

Stone & Webster clients produce over
3.2 billion pounds of ethylene annually
in 37 plants in 12 countries.

This world record of ethylene engineering
experience is available to you.
Call or write our nearest office.

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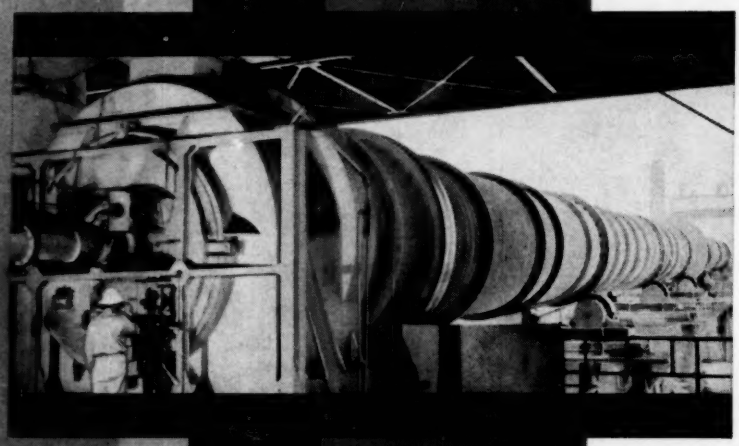
TRAYLOR FIRST



Why this 1933 first welded kiln could be the key to your company's profits in the 60's

For the simple well-proved reason that they're better, kilns of all-welded construction are pretty much "standard" today. Important to keep in mind: the standard was set by Traylor . . . builder of the first welded kiln in 1933.

A radical innovation a generation ago —but why so important now? First and obviously, it means that Traylor has the longest record of experience in this special kind of equipment.

More important still: It's merely one example of Traylor's coming up first with new ideas to meet changing needs. Benefits of other Traylor "firsts"—some dating before 1933, many since—are being reaped today throughout the industry, quite likely already including your own plant. Traylor built, for example, the first 60-inch primary gyratory crusher and the first large ball mill.

Today Traylor's proved capacity to pioneer sound innovations in kilns, mills and crushers is enhanced by expanded research capabilities and process know-how.

Up-to-date facilities and a long, impressive record of past "firsts" are a good combination of reasons to call on Traylor first when you're planning for efficient operation in the changing business climate of the sixties.

See Chemical Engineering Catalog for details and specifications.

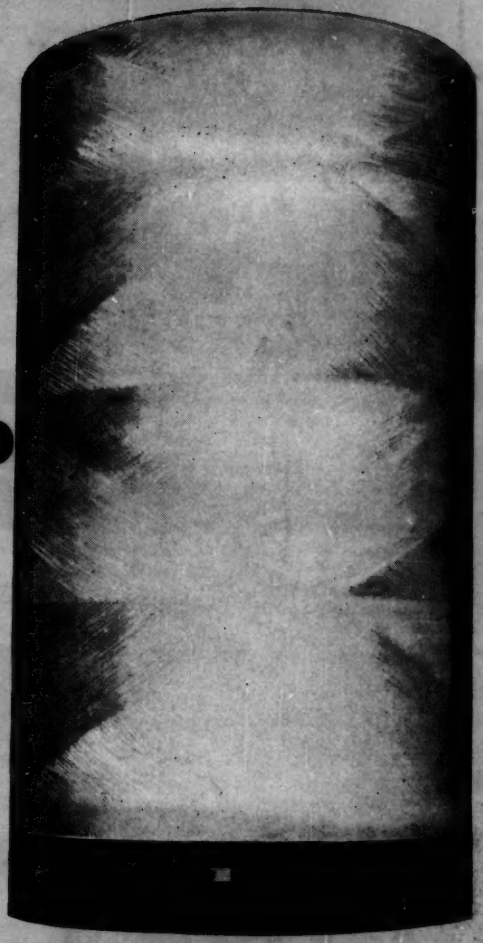
Traylor

TRAYLOR ENGINEERING & MANUFACTURING

DIVISION OF FULLER COMPANY

1551 MILL STREET • ALLENTOWN 1, PA.

4492
TKA-15



from
ACETIC ACID
to
XYLENE...

More than 200 corrosive chemical compounds can be handled safely and economically in

POXYGLAS™ TANKS

POXYGLAS is a trade mark of Black, Sivalls & Bryson, Inc.

If you are concerned with the storage or processing of corrosive materials, or product contamination—POXYGLAS Tanks are your likeliest answer.

Why? 3 to 4 times as strong as conventional reinforced plastic tanks. No maintenance costs for corrosion inspection or recoating. 1/6 the weight of comparable size welded steel tanks. POXYGLAS Tanks—produced by a machine operation—are constructed of continuous glass filaments impregnated with epoxy resin and wound under tension over a mandrel in a calculated, controlled pattern for maximum strength, consistent quality. Production manufacturing methods mean maximum corrosion protection at minimum cost.

STANDARD TANK SIZES:

NOMINAL CAPACITY (gallons)	DIAMETER (feet)	HEIGHT (feet)
4,500	10	8
9,000	10	15
12,500	12	15
17,000	12	20

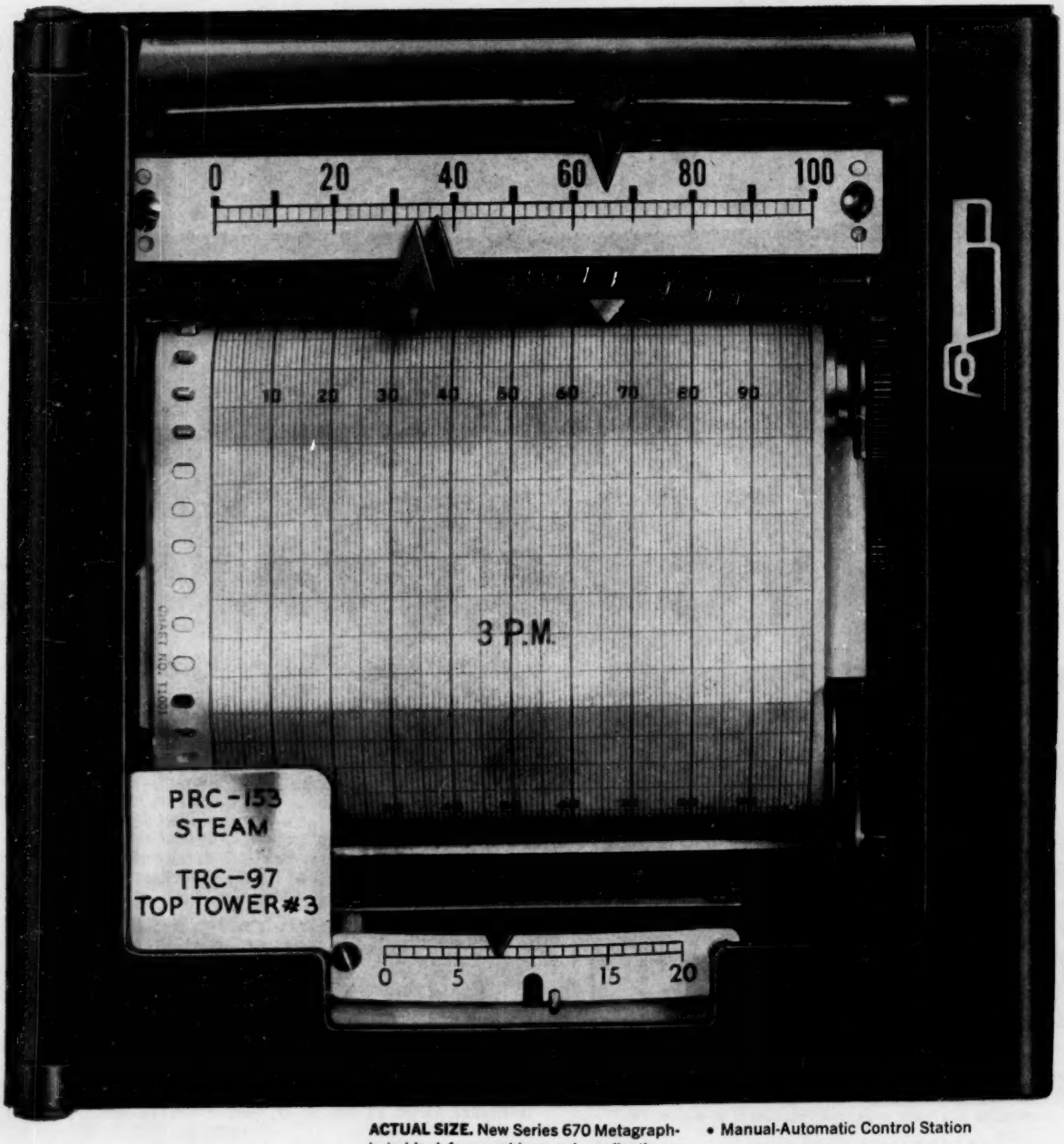
Want a POXYGLAS Corrosion-resistance Chart to see if your chemicals can be handled in POXYGLAS Tanks? Write to BS&B, Dept. 17-N5, P. O. 749, Ardmore, Okla.

BS&B

BLACK, SIVALLS & BRYSON

KANSAS CITY • ARDMORE • OKLAHOMA CITY • TULSA

NEW..



ACTUAL SIZE. New Series 670 Metagraphic is ideal for graphic panel applications, occupying panel space only 7" wide by 7⅛" high. Fits into 6" by 6" panel cutout. Typical 670 Series models available, include:

- 1-Pen, 2-Pen, or 3-Pen Receiver
- Manual-Automatic Control Station
- Manual-Cascade Control Station
- Manual-Automatic-Cascade Control Station
- Single-Case Cascade Control Station

here's the pneumatic receiver you asked for!

Bristol's new 4-inch-chart Metagraphic receiver is the easiest yet to install, operate, and service

Never before has a 3-15 psi pneumatic receiver been designed with such exacting, meticulous attention to the needs of the graphic panel designer, the instrument user, and the instrument maintenance man.

Bristol's new Series 670 Metagraphic receiver brings you the plug-in versatility and operating convenience—made famous in previous Metagraphic pneumatic receivers—plus the increased legibility and accuracy of a 4-inch strip chart, plus these big new features:

Simplified control switching between functions... allows the easiest start-up procedure for either the common manual-automatic station or the more complex, single-case cascade control station models. Intermediate "seal" position has been eliminated. Just adjust process to line-up color-coded indicators and switch to automatic or cascade operation as desired.

Uniform control switching . . . all receiver models have the same switch positions for the various types of control —cascade position, 3 o'clock; manual position, 6 o'clock and automatic position at 9 o'clock.

Simplified chart change and inking . . . chart changing is a one-hand operation. A new chart can be slipped into place in an instant. The capillary inking system can be refilled from the front of the receiver.

And the new Metagraphic receiver gives you other outstanding features such as rectilinear chart coordinates for easiest reading, easy connections for any type of control, either field or receiver-mounted controllers; and sparkless, mercury-switch disconnect of electrical circuit when chassis is removed.

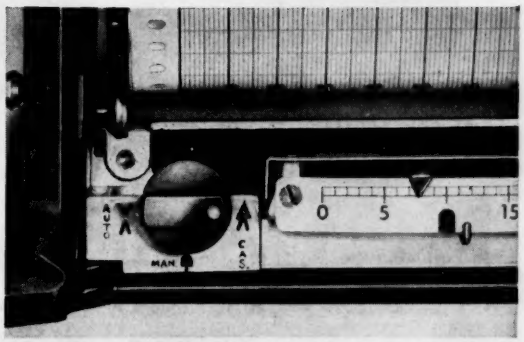
Get the complete story on the new Bristol Metagraphic receiver today. Write The Bristol Company, 109 Bristol Road, Waterbury 20, Conn., a Subsidiary of American Chain & Cable Company, Inc. 0.42

ACCO

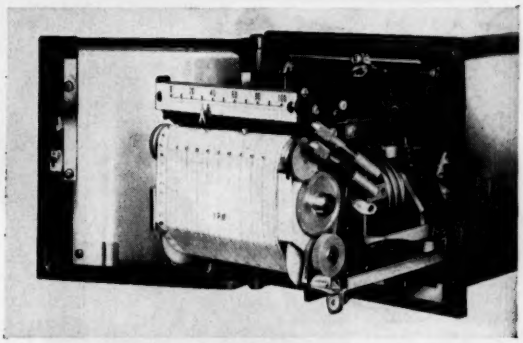
BRISTOL

...for improved production through measurement and control

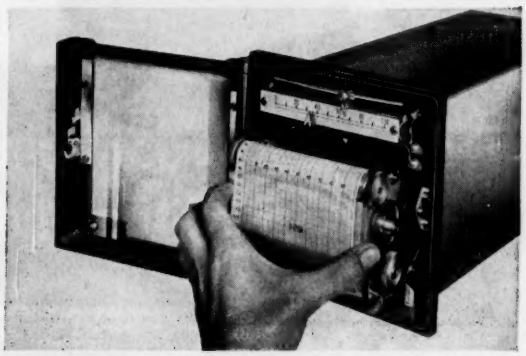
AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS



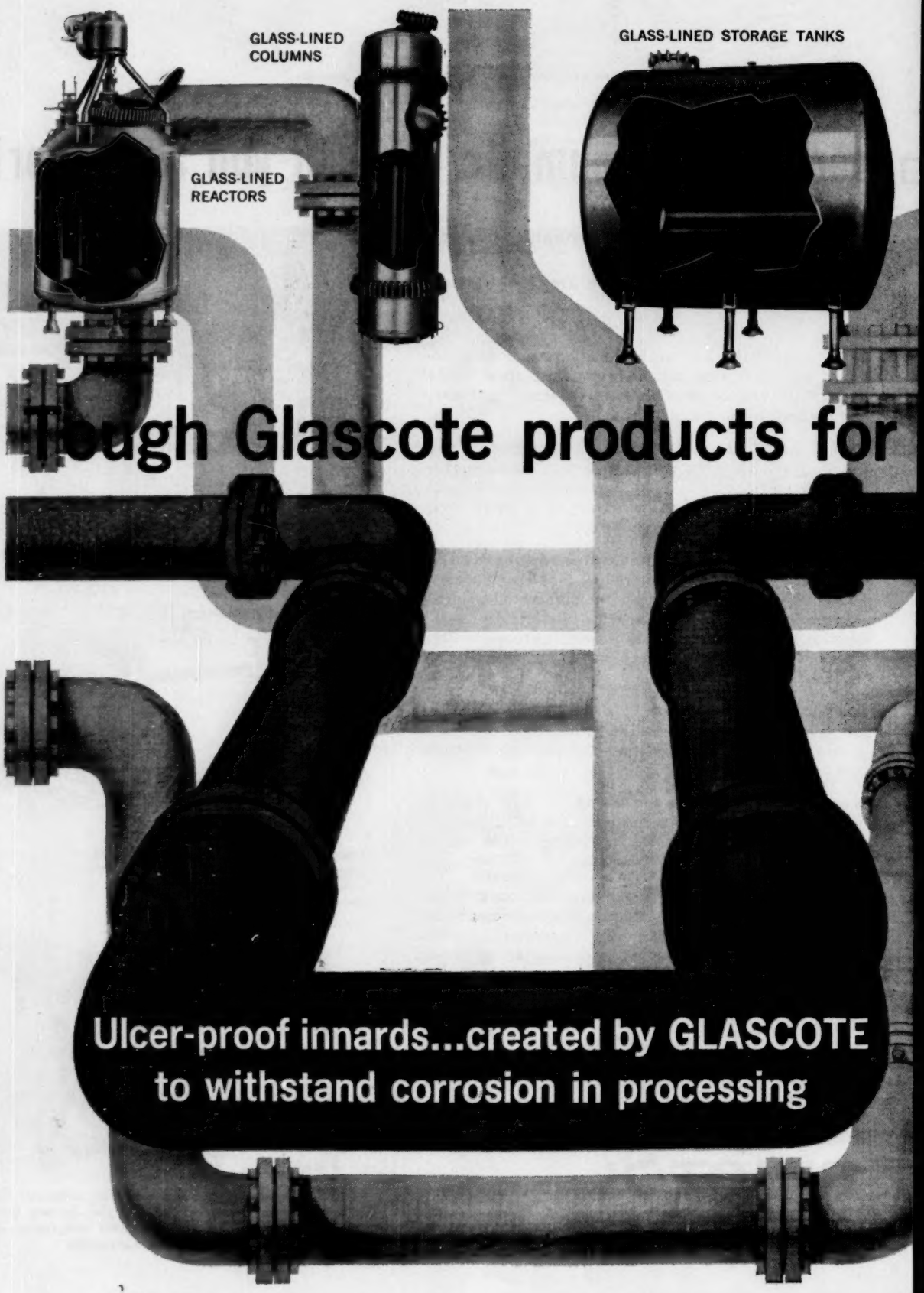
Simplified control switching is keynote of new receiver's design. For instance: uniform switch positions on all models avoid operator confusion in multi-receiver installations; simple alignment of color-coded pointers and a single switching operation put complex automatic or cascaded systems "on stream."



Complete "plug-in" service continuity. Entire plug-in receiver chassis is instantly replaceable with spare for complete continuity of service. Control functions are not disturbed when receiver chassis is removed.



Easiest to service . . . For instance: Easily removable chart drive mechanism—a one-handed operation—permits exceptionally fast chart replacement; just slip out drive, replace with spare, replace paper in original drive at leisure.


GLASS-LINED COLUMNS
GLASS-LINED STORAGE TANKS
GLASS-LINED REACTORS
Tough Glascote products for
Ulcer-proof innards...created by GLASCOTE
to withstand corrosion in processing

every stage of your process

Glascote products give a process reliable protection against corrosive agents and contaminations. Glass-lined protection means extra years of service . . . lower operating costs.

Glascote glass-lined equipment guarantees product purity . . . greatest versatility for processing products . . . new outstanding resistances to acids. Vessels lined with Glascote's unique 778, for example, extend acid resistance to 75° F higher operating temperature. And 778 is only one of more than 3000 Glascote glass-lining formulations.

Glascote offers complete engineering service, too! Each process is thoroughly analyzed by highly experienced Glascote experts who make specific mechanical proposals carefully worked out to individual needs. And after the installation has been made, Glascote backs it up with personal, direct, prompt maintenance care.

For efficient, economical, reliable glass-lined processing equipment, insist on Glascote . . . insist on a long life for your process!

Get specific product data from your Glascote representative. Or, send for new Glascote Products Bulletin No. 105. Glascote Products, Inc., Cleveland 17, Ohio.

Through research . . . a better way

A.O.Smith
CORPORATION

Subsidiary
GLASCOTE PRODUCTS, INC.
Cleveland 17, Ohio
World's largest manufacturer of glass-protected steel products.

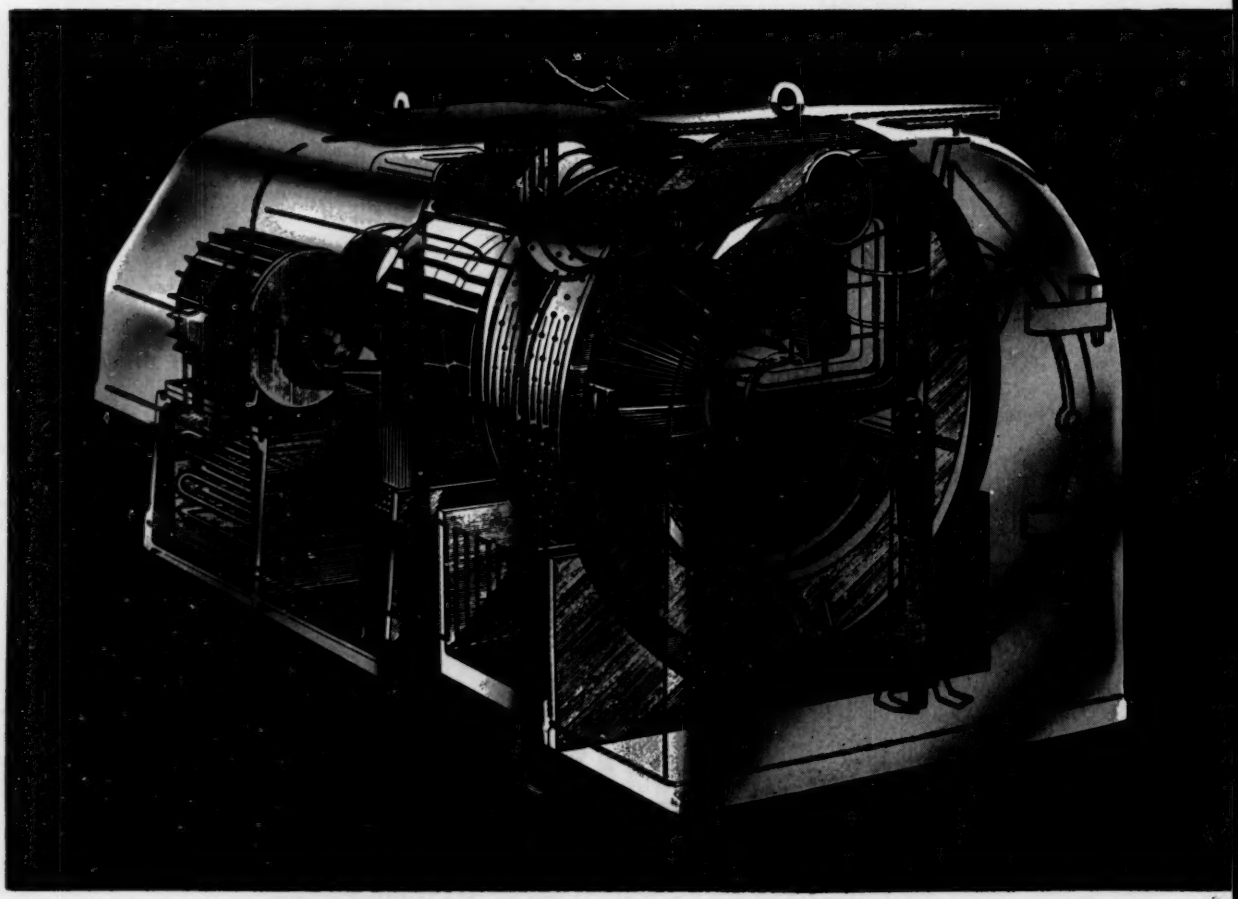
BAKER PERKINS CENTRIFUGALS

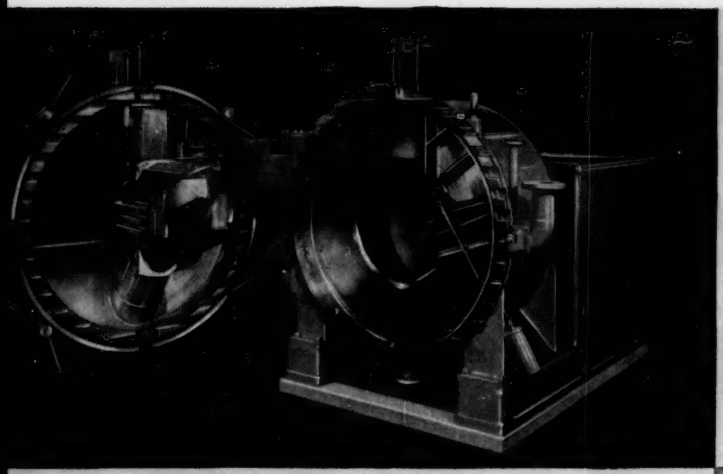
FOR ECONOMICAL SEPARATION OF FILTERABLE SOLIDS

Baker Perkins centrifugals have an enviable reputation for efficiency and economy in centrifugation. The well known Baker Perkins continuous pusher type and automatic universal centrifugals have been used successfully for years to separate many different filterable solids. Now with a multi-stage continuous pusher type centrifugal and an automatic vertical pusher type centrifugal, there is a Baker Perkins centrifugal to separate both slow draining solids and extremely fragile crystals. All Baker Perkins centrifugals are manufactured in many sizes, many different materials of construction and with special design features to meet your process requirements.

B-P (ESCHER-WYSS) MULTI-STAGE CENTRIFUGALS

Continuous centrifugation of difficult-to-handle materials is now possible with new B-P (Escher-Wyss) Multi-Stage Continuous Centrifugals. The continuous multi-stage pusher centrifugal eliminates cake buckling, assures adequate retention time, speeds release of liquids, improves washing, provides better separation of multiple liquid components and reduces power consumption. Models are available with capacities from 1½ tons to 45 tons per hour.



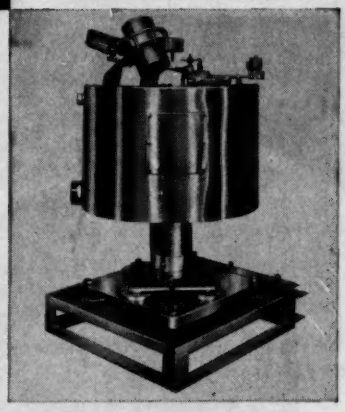


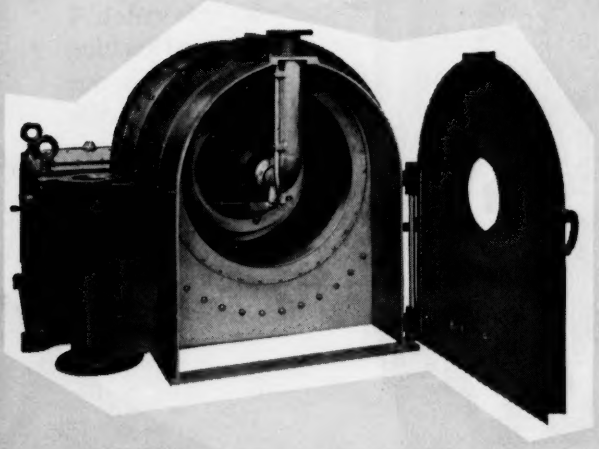
PRESSURE CENTRIFUGALS

The B-P HS 40W is one of a line of pressure centrifugals built for normal operation at 1000 times gravity and pressures up to 150 PSIG. Many new features include: a self-seating, self-aligning door seal, housings that withstand extreme operating pressures, new type discharge knife and chute, and a peeler knife that enters the cake at successively increasing depths, thus eliminating cake glazing.

VERTICAL CENTRIFUGALS

The new Baker Perkins VS-20 Vertical Centrifugal is designed and built to handle friable crystals during charging without danger of crystal degradation. The unit is charged with slurries while running at reduced speeds, then automatically accelerates for the drying and washing operations and automatically decelerates for discharge.



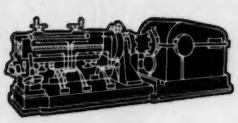


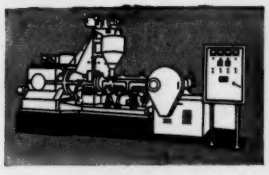
CONTINUOUS CENTRIFUGALS

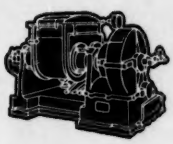
The B-P Type S Centrifugal has continuous feed and discharge requiring no timing or cycle controllers. It is ideal for centrifuging a wide range of relatively free-draining crystalline materials. Friable solids are handled easily since there are no scrapers, baffles, rakes or plows to cause crystal degradation. Models are available with capacities up to 54 tons per hour of solids.

403

BAKER PERKINS INC.







CONTINUOUS MIXERS • PLASTICS MACHINERY • UNIVERSAL MIXERS

SAGINAW, MICHIGAN

MASONEILAN

ELECTROPNEUMATIC POSITIONER...

Arranges Happy Marriage

Between Electronic Controller and Pneumatic Control Valve

The advantages of the electronic controller can now be mated to the superior power and smooth throttling action of the pneumatic control valve by means of Masoneilan Model 8010 Electropneumatic Positioner — the most advanced device available for converting electric output signal to pneumatic positioner output.

Fidelity of positioning is assured because Model 8010 is a true positioner providing *direct* comparison of valve stem position with controller output signal, resulting in dynamic response and accuracy *not possible with any combination of transducer and positioner.*

Compatibility with any presently available electronic controller is obtainable because design provides for adaptability to all usual controller output signals.

Character of the design results in high open-loop gain and closed-loop stability. Balanced beam permits installation of the valve in any position without calibration shift.

You Are Invited to join the growing number of users who recognize the superior merits of Masoneilan Electropneumatic Positioners. The first step — obtain complete information. Get in touch with any Mason-Neilan office or representative; or write direct to

MASONEILAN

Products that work for your profit

MASON-NEILAN

Division of Worthington Corporation

23 Nahatan Street, Norwood, Massachusetts

DESIGN FEATURES

- Extra large stabilized magnet, plus efficient magnetic circuit, provides high-force changes.
- External stroke adjustment accessible without removal of cover — no exposure of electric wiring.
- High capacity relay for fast stroking speeds. Relay may be mounted in any one of four positions to facilitate piping.
- Balanced beam permits installation of valve in any position without shift in calibration.
- Available for 3-15 psi or 6-30 psi valve spring ranges and for split-ranging. Standard stroke ranges ⅜" – 3" and 2" – 4". Others available.
- Available with direct or reverse action and for direct or reverse actuators.
- Explosion-proof construction meets requirements of Class I, Division I, Group D.

PERFORMANCE DATA

Open-loop Gain* — approx. 100

Linearity—within ±1% of full stroke

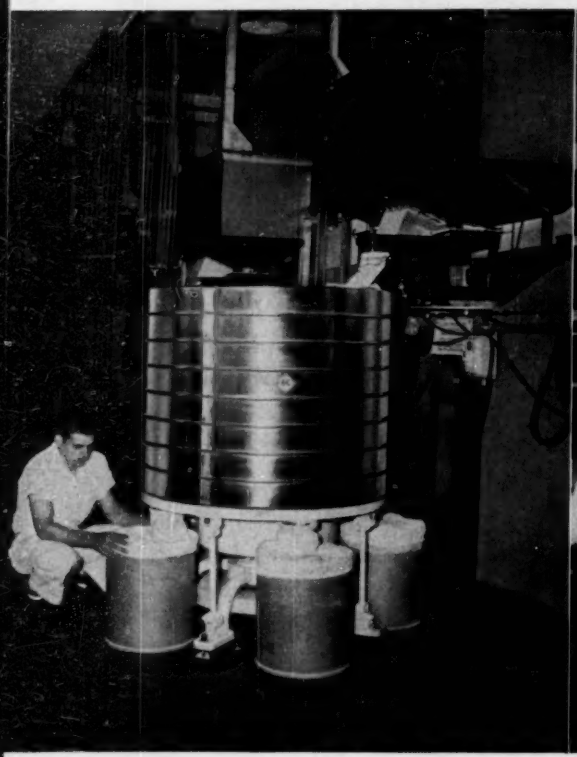
Repeatability — within 0.2%

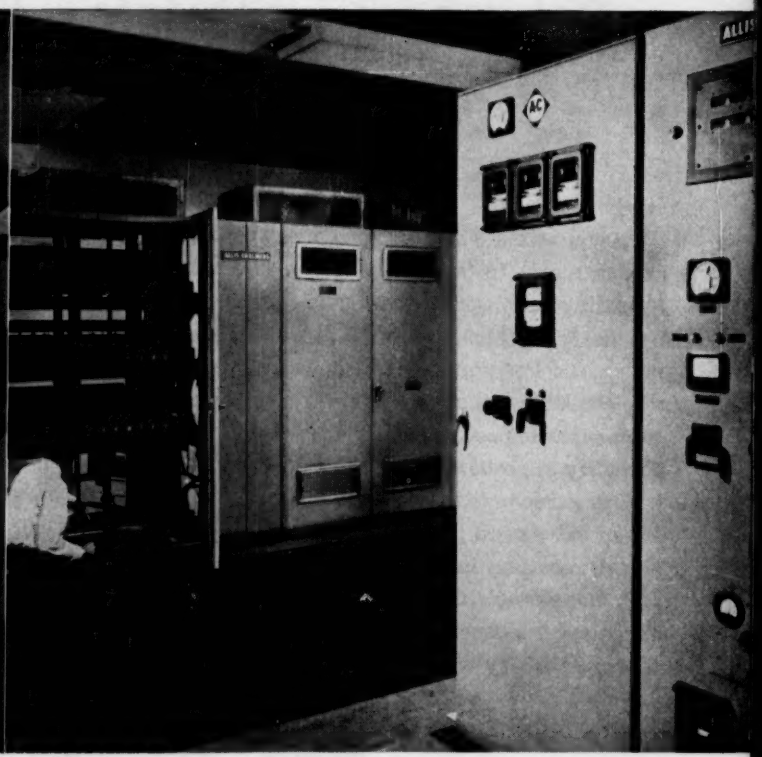
Load Sensitivity — output pressure change of 1.2 psi per 0.1% of full stroke offset

Supply Pressure Effect — ±1% of full stroke for ±5 psi change from 20 psi

*Defined as $\frac{\%\text{ of full stroke}}{\%\text{ of full input range}}$

ideas and news:





Up to 35 square feet of screening area in only 16 square feet of floor space: Stacked-deck design of this gyratory screen conserves valuable space. Cuts maintenance, downtime with all-stainless-steel construction. Abrasive or corrosive materials, dry foods and pharmaceuticals are handled with care. Gentle, quiet, vibrationless operation means minimum disintegration of fragile particles.

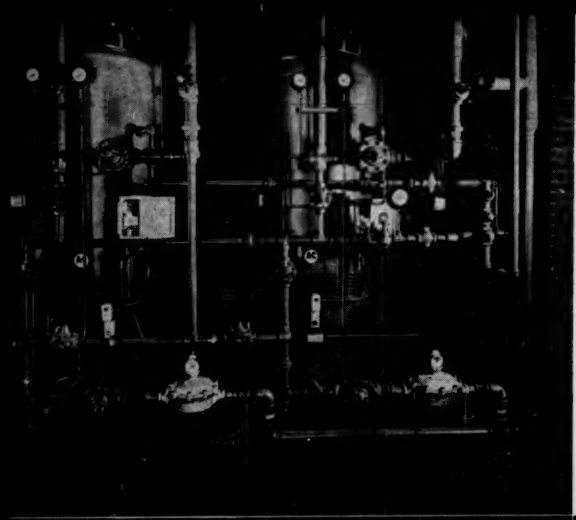
Silicon rectifiers can be located anywhere in the plant. Designed especially for large electrochemical or industrial applications where space, heat or dirty atmospheres are a problem, these silicon rectifiers employ water-to-water heat exchanger equipment. No special room is required — no need for clean air for cooling. Smaller compartment sizes save floor space. Cells can be removed without disturbing the cooling system. Reactor cores eliminate need for matched cells, surge capacitors protect against voltage surges, and current-limiting fuses provide cell protection.

Which of these productive ideas could be working for you?

A continuous mechanical agglomeration process that makes waste materials pay. A steam turbine-generator with dual-purpose flexibility. A gyratory screen that saves space. These examples demonstrate the extra value that is standard with Allis-Chalmers . . . the greater efficiency and the added productivity which are yours when you buy A-C products, systems and services. Call your Allis-Chalmers representative for details on A-C "worth-more" features. Or write Allis-Chalmers, Industries Group, Milwaukee 1, Wisconsin.

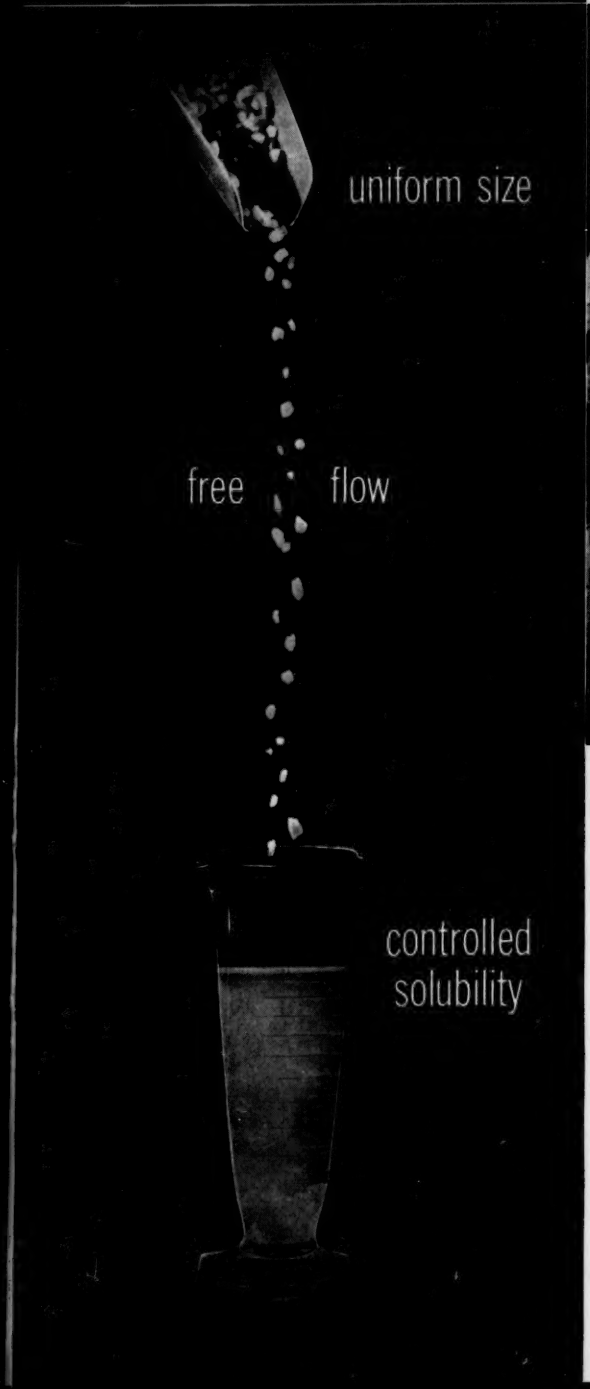
Compactor is an Allis-Chalmers trademark.

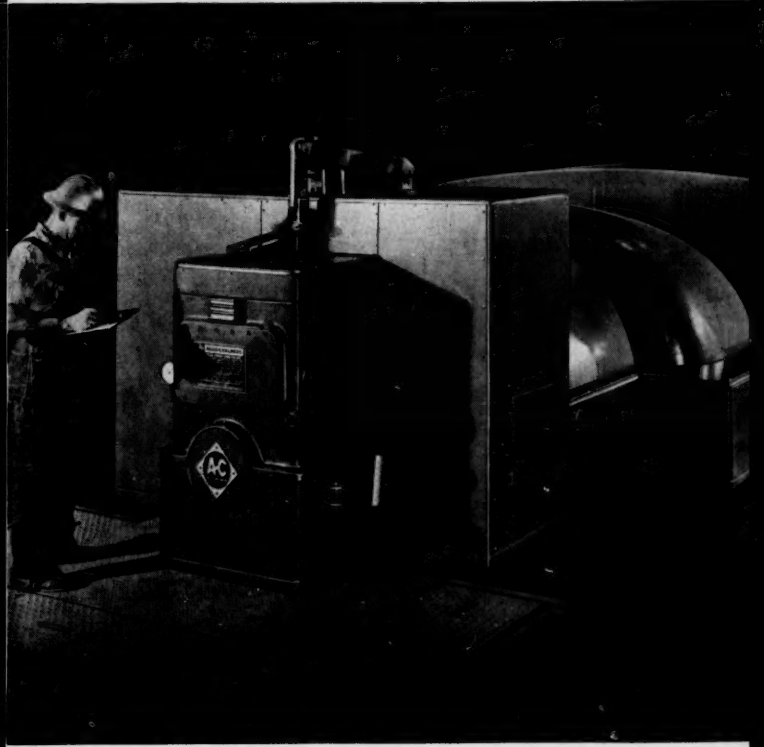
A-1480



Calcium and magnesium are the "vandals" that cause scale in pipes and boilers, clog systems and mean heavy use of cleaning compounds. ZEOLITE is their natural enemy! An A-C zeolite water softener means a simple switch to sodium ions from the usual hardness present in most water supplies. Once A-C conditioned, the "softened" water finds ready use in chemical plants to end scaling problems.

Even the by-product makes an economy contribution: Versatile . . . describes these two 6250-kw condensing, automatic extraction steam turbine-generator units installed in a midwest petrochemical plant. A typical application supplying steam to a process with electric power as an economical by-product. A-C manufactures a complete line of condensing and non-condensing turbine-generator units, with or without automatic extraction, for the chemical industry. For complete information on types and ratings from 2000 kw to the largest, ask for bulletins 7654A and 9448.

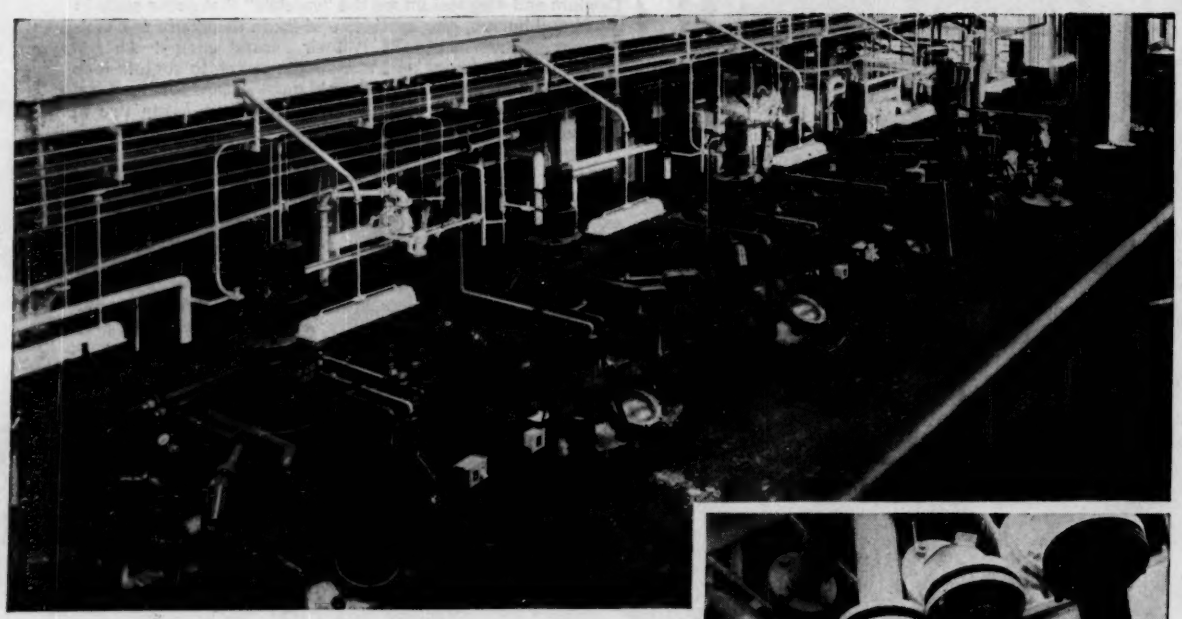




Profit recovery starts with waste: The continuous mechanical compacting process recovers virtually 100% of waste fines! It compacts and screens your waste material into flakes. Then granulates them into desired product. The same process tightens your production controls when you face problems involving granular size, density, solubility and other physical properties. Integrates smoothly into your system. Requires less power, lower capital investment than less modern agglomeration methods.

ALLIS-CHALMERS PRODUCTS FOR THE CHEMICAL INDUSTRY: Look to A-C for atomic, thermal and hydro electrical generating equipment; Compactor mills; compressors; control; coolers; crushers; dryers; earth-moving equipment; engines; grinding mills; industrial systems; kilns; lift trucks; motors; pumps; rectifiers; screens; switchgear; tractors; transformers; unit substations.

ALLIS-CHALMERS



R/M RUBBER HOSE
Helps Hold Costs *Down*
in Modern Chemical Plants

For example, at the new ultra-modern plant of Toms River—Cincinnati Chemical Corporation at Toms River, New Jersey—R/M custom-engineered hose saves manhours and protects vital processes. That's because R/M engineering made certain the *right* hose was made and supplied for each process function. Typical are the lines on the huge Manhattan rubber lined kettles shown above. The lengths of hose at right are specially engineered and equipped with leak-proof Hydro-Lok flanges to overcome process pipe-line problems. Throughout the Toms River plant, R/M hose constructions meet specialized job requirements handling corrosive chemicals and similar process solutions.

You can expect the same "engineering" with the R/M hose you specify for your plant. Easy handling Homoflex is ideal for wash-down operations, or wherever you use air or water hose for general service. For handling chemicals and acids, there's R/M Teflon Lined Hose and Condor Acid Hose available with rubber, neoprene, Butyl or Hypalon tube as required for specific conditions. Condor Flexible Pipe can outlast iron or steel as much as 10 to 1 for highly abrasive or corrosive solutions. R/M Rubber Expansion Joints will eliminate pipeline stresses, misalignment and vibration.

Depend on your R/M representative to suggest the engineered R/M hose construction to help you hold costs down—give you "More Use per Dollar" on every job.

RM 1011

ENGINEERED RUBBER PRODUCTS ... MORE USE PER DOLLAR

RAYBESTOS-MANHATTAN, INC.
MANHATTAN RUBBER DIVISION, PASSAIC, NEW JERSEY

Att'n:
Kiln Operators with Gas Cleaning Problems on Lime, Coal, Cement, Asphalt or Aggregate

For air pollution control, and for solids recovery from kiln gases, the S-F Venturi scrubber's unique design assures reliable performance without maintenance problems. The Chemico S-F scrubber was specifically designed to permit the recycle of slurries with high solids content. It has no nozzles, trays or jets to plug, and it completely eliminates build-up at the gas inlet.

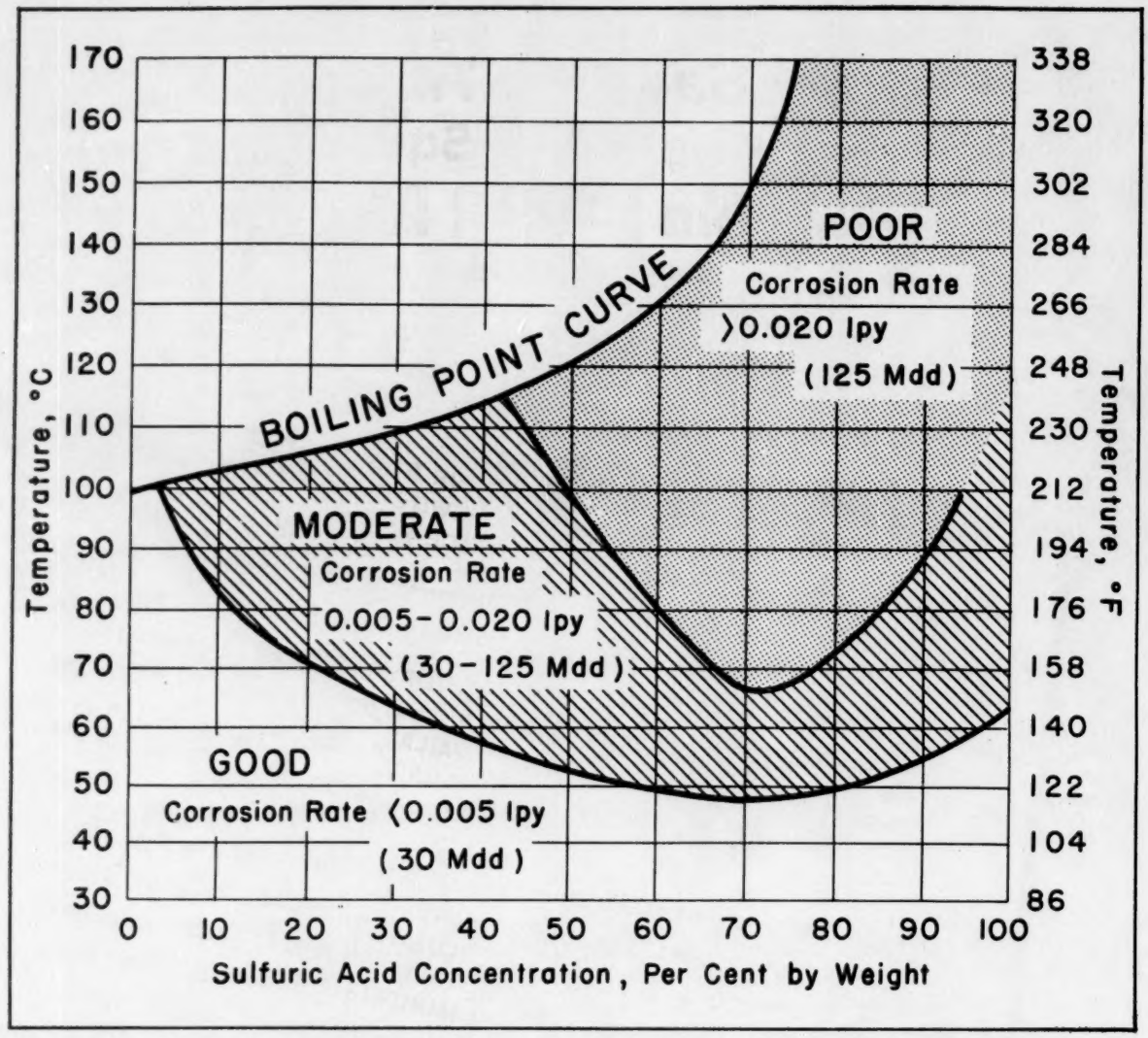
Chemico S-F Venturi scrubbers are now operating efficiently on kilns throughout the country. For example, a unit installed one year ago on a reburnt lime kiln in California has never caused a kiln shutdown. This Venturi scrubber is designed to handle 35,000 Cfm of hot gases flowing at 450°F. It provides gas cleaning efficiencies of 99%+ on lime dust and 90%+ on soda fumes, resulting in a clean stack.

If you are considering the installation or replacement of gas cleaning equipment, learn more about Chemico scrubbers by writing to: CHEMICO—Gas Scrubber Division. All inquiries will receive prompt attention.

CHEMICO

Chemical Construction Corporation, Gas Scrubber Division
320 Park Ave., New York 22, New York

FERNDALE, MICH. CHICAGO, ILL. LOS ANGELES, CALIF. HOUSTON, TEX. BARTOW, FLA. BIRMINGHAM, ALA. PITTSBURGH, PA.



Iso-Corrosion chart for Ni-o-nel alloy in sulfuric acid, based on laboratory data using pure acid.

How Ni-o-nel alloy resists attack by hot sulfuric acid

The few seconds it takes to read this chart may very well give you a practical answer to acids handling problems.

Ni-o-nel* nickel-iron-chromium alloy resists sulfuric acid solutions of up to about 40% concentration by weight at boiling temperature and up to 60% at 176°F. Moreover, it has good resistance to *all* concentrations at room temperature. The presence of oxidizing salts usually steps up corrosion resistance even more. That's why Ni-o-nel alloy is so suitable for mixtures containing nitric acid, cupric sulfate and ferric sulfate.

Readily welded. The metal-arc welding of Ni-o-nel alloy follows standard welding procedures employing a "135*" Ni-o-nel electrode. And, you exercise the same normal precautions about cleanliness of surface, use of annealed material, and removal of all slag before depositing successive beads in a multi-pass weld. Or you can use the tungsten-inert gas process equally well, with "65*" Ni-o-nel filler metal.

To get detailed information on Ni-o-nel alloy, write for booklet T-37, "Engineering Properties of Ni-o-nel."

You'll get concrete facts on the remarkable corrosion resistance . . . the unique weldability for economical fabrication . . . of this alloy. For help in selecting materials to hold hard-to-handle corrosives, contact us. Our engineers will gladly provide the metallurgical information you want. *Inco trademark

HUNTINGTON ALLOY PRODUCTS DIVISION
The International Nickel Company, Inc.
Huntington 17, West Virginia

NI-O-NEL®

SPACE–
TIME–
MONEY—

Save All Three with Square D QMB POWER PANELBOARDS

MOTOR STARTERS AND BREAKERS OR SWITCHES COMBINED IN ONE SPACE-SAVING PANELBOARD!

FACTORY-WIRED AND ASSEMBLED OR ENCLOSURES AND COMPONENTS AVAILABLE FROM YOUR SQUARE D DISTRIBUTOR!

BREAKER AND SWITCH UNITS ARE EXCLUSIVE PLUG-IN CONSTRUCTION. INSTALLED OR REARRANGED IN MINUTES!

If the above installation had been made the old way —with trough, and ganging separate switches and starters—it would have taken at least six feet of wall space instead of 30 inches, and four times the installation time.

After this panelboard is installed, Square D's exclusive *PLUG-IN* design permits circuit changes without costly down time. For extra safety, plug-in units are mounted directly above starters, permitting interlocking. No starter or disconnect door can be opened when switch is "ON."

QMB panelboards accommodate reversing or non-reversing starters, sizes 0 through 4; plug-in circuit breakers through 225 amperes; plug-in switches through 200 amperes (bolted through 600 amperes).

Twin Unit (above) available 15-100 amperes
Single Unit available 125-225 amperes

Exclusive Breaker Unit Advantages:
Plug-in construction • Each unit in individual steel enclosure with dead-front construction • Combine switch and breaker units in same panelboard, if desired

Write for the complete story—Square D Company, Mercer Road, Lexington, Kentucky

SQUARE D COMPANY

wherever electricity is distributed and controlled

WAGNER®
MOTORS
AT
WORK

power to make ammonia

100 hp Wagner® explosion-proof motor provides safe, all-weather drive for gas reform induced draft fan

The motor: a totally-enclosed, fan-cooled Wagner Type JP-1. It's the perfect power package for the fan it drives in the Phillips Pacific Chemical Corporation plant at Kennewick, Washington. It is completely explosion-proof—protected against dust, dirt, abrasives and fumes, and is capable of operating for long periods under critical conditions without maintenance.

Now, your end products may be aluminum awnings or axes instead of anhydrous and aqua ammonia. But you do use electric motors. And we've got motors that will keep your production rates up . . . motors with a wide variety of enclosure types and mountings in ratings through 1000 horsepower. Design-wise, they'll please your most demanding engineer. Work-wise, they'll please you, for they get the job done.

Wagner motors have been getting the job done for over 65 years. What's more, our program of constant research and development in electric motor design makes sure that Wagner motors will continue to lead where it counts . . . in performance. Call your Wagner Sales Engineer for an analysis of your next motor application, be it for plant or product.

Branches and Distributors in all Principal Cities

Wagner Electric Corporation

6407 PLYMOUTH AVENUE, ST. LOUIS 33, MO., U.S.A.

Wagner Type JP motors are built with rugged, corrosion-resistant cast iron frames. Both ends of these motors have running shaft seals to keep the heavy-duty bearings clean. Bearings can be relubricated to add years to life of motors that operate under severe conditions.

WH61-9

Y news briefs

from **Yarnall-Waring Company,** *Philadelphia 18, Pa.*

BRANCH OFFICES IN 19 UNITED STATES CITIES • SALES REPRESENTATIVES THROUGHOUT THE WORLD
STEAM TRAPS STOCKED AND SOLD BY 270 LOCAL INDUSTRIAL DISTRIBUTORS

USE THIS YARWAY STEAM TRAP TO KEEP YOUR DRYERS, COOKERS, TANK COILS AND OTHER PROCESSING EQUIPMENT OPERATING AT PEAK EFFICIENCY

Yarway Series 60 Impulse Steam Traps are the traps "designed with high production in mind." They get processing equipment hotter, sooner—and keep it hot. Here's how:

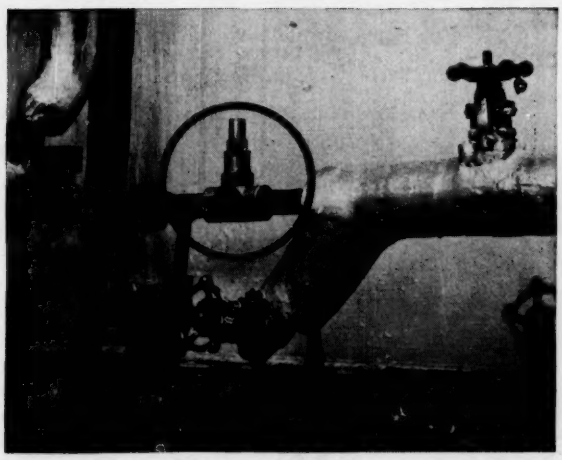
The only moving part, a small stainless steel valve, literally "floats on the condensate load." When equipment is started up, and condensate load is heavy, it opens wide and discharges at full capacity to bring equipment to operating temperature as quickly as possible.

In operation, it continuously senses condensate temperature, discharging each bit of condensate as it forms instead of storing up a bucketful. Result—higher temperatures, more even temperatures, more productive equipment.

Other Yarway features—small size, light weight, good for all pressures, low maintenance, stainless steel.

Yarway pioneered the impulse trap with its unique thermo-dynamic principle over 25 years ago. Most users find among Yarway's full line of impulse traps the profitable and productive solution to their steam trapping problems—you can too!

You can get Yarway's latest steam trap Bulletin T-1743, or a free 60-day trial of any Yarway Steam Trap, by writing Yarnall-Waring Company or contacting your local Industrial Distributor.



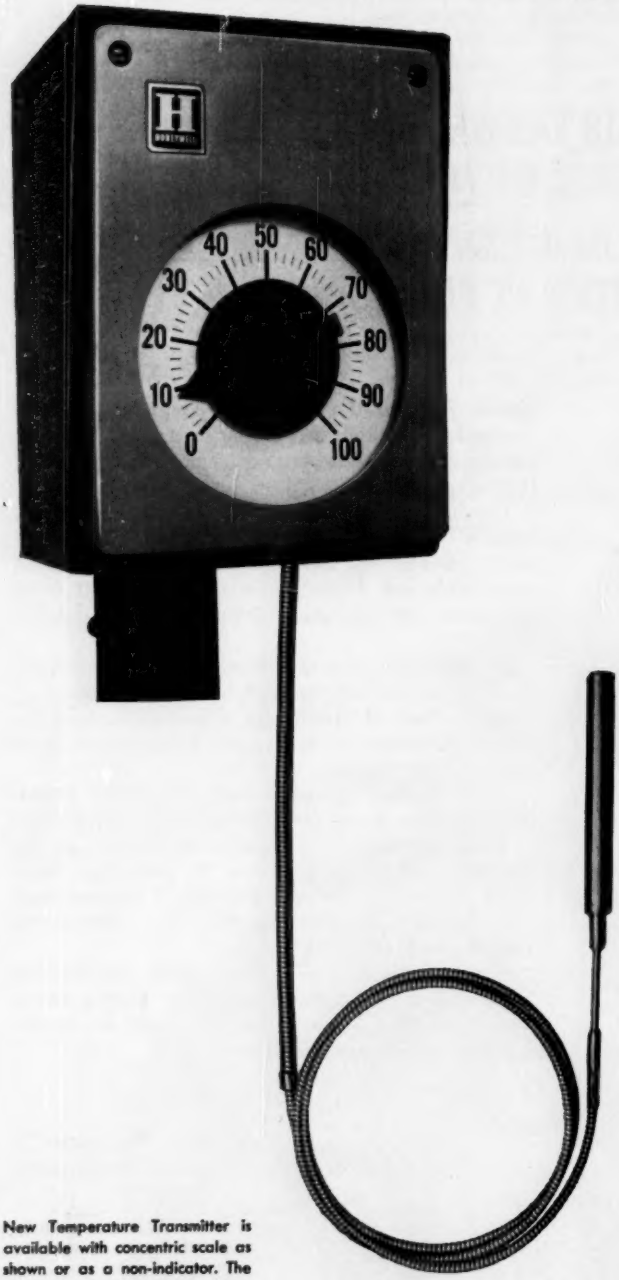
¾" Yarway Impulse Steam Trap draining tank coils on sulfur storage tank, 175 lbs. pressure

YARWAY OFFERS IMPULSE STEAM TRAPS FOR THESE SPECIFIC OPERATING CONDITIONS

AVERAGE CONDENSATE LOADS	EXTRA HEAVY CONDENSATE LOADS	LIGHT CONDENSATE LOADS
Series 60	Series 40	No. 30

NEW TEMPERATURE TRANSMITTER

offers thermal system options with ranges from −125° to 1000°F



New Temperature Transmitter is available with concentric scale as shown or as a non-indicator. The unit transmits with calibrated accuracy of ±0.5% of full scale, and indicates within ±1.0% of full scale.

Completely new, completely flexible, the new Honeywell Temperature Transmitter gives you a choice of either gas or mercury thermal system plus a wide selection of measuring bulb styles. Die-cast aluminum case is 4″ by 7″ by 9″. Concentric scale is 8½″ long.

New built-in rebalancing capsule automatically compensates for changes in ambient temperature. Two-way overload protection covers 100% of span. Maintenance is greatly simplified by modular construction which lets you remove any major component by loosening two screws. All field adjustments are easily accessible, and a self-locking feature prevents upset after calibration adjustments are made.

Transmitter Features: Gas (—125° to 800°F) and mercury (—40° to 1000°F) actuated thermal systems with bulbs for any application. Mount on pipe welded to flow line, or on bracket that clamps on the hex head of the socket. Vibration resistant thermal system means accurate measurement on vibrating flow lines.

For more complete details on the new Temperature Transmitter, call your nearby Honeywell field engineer. Or write for *S630-1*. MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa. In Canada, write Honeywell Controls, Ltd., Toronto 17, Ontario.

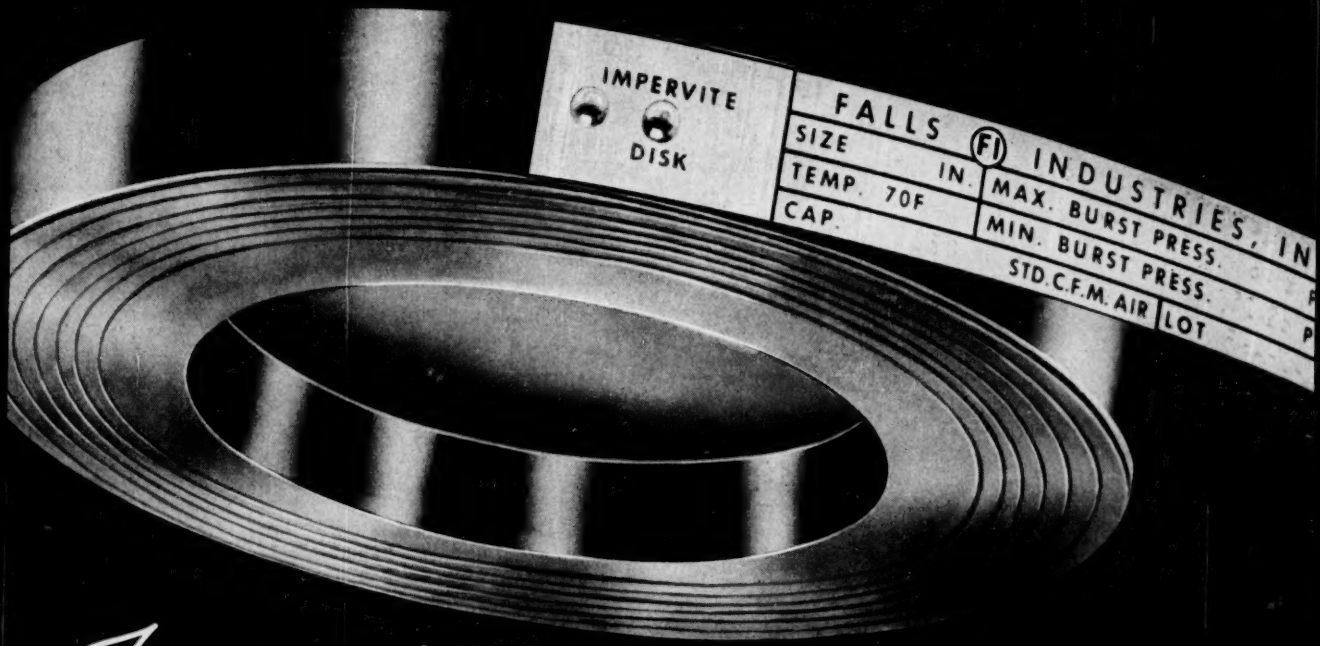
Honeywell

First in Control

SINCE 1885

HONEYWELL INTERNATIONAL Sales and Service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

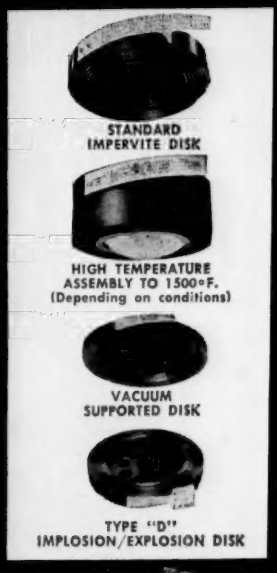
. . Perfect Overpressure Protection from FALLS (FI) INDUSTRIES



Impervite IMPERVIOUS GRAPHITE RUPTURE DISKS

From 1-inch to 3-feet, to 300 psi, to 1500°F.
Standards delivered immediately from stock

TRULY RELIABLE — because Impervite Disks do not fatigue, maintain constant burst characteristics at all temperatures — are immune to effects of thermal shock — are unaffected by action of practically all corrosives — provide ±5% burst accuracy — mount in standard A.S.A. flanges... are furnished in 4 standard types described at right.



FALLS (FI) INDUSTRIES, INC.
AURORA ROAD SOLON, OHIO
Phone: CHurchill 8-4343 TWX: CGN-FS-720

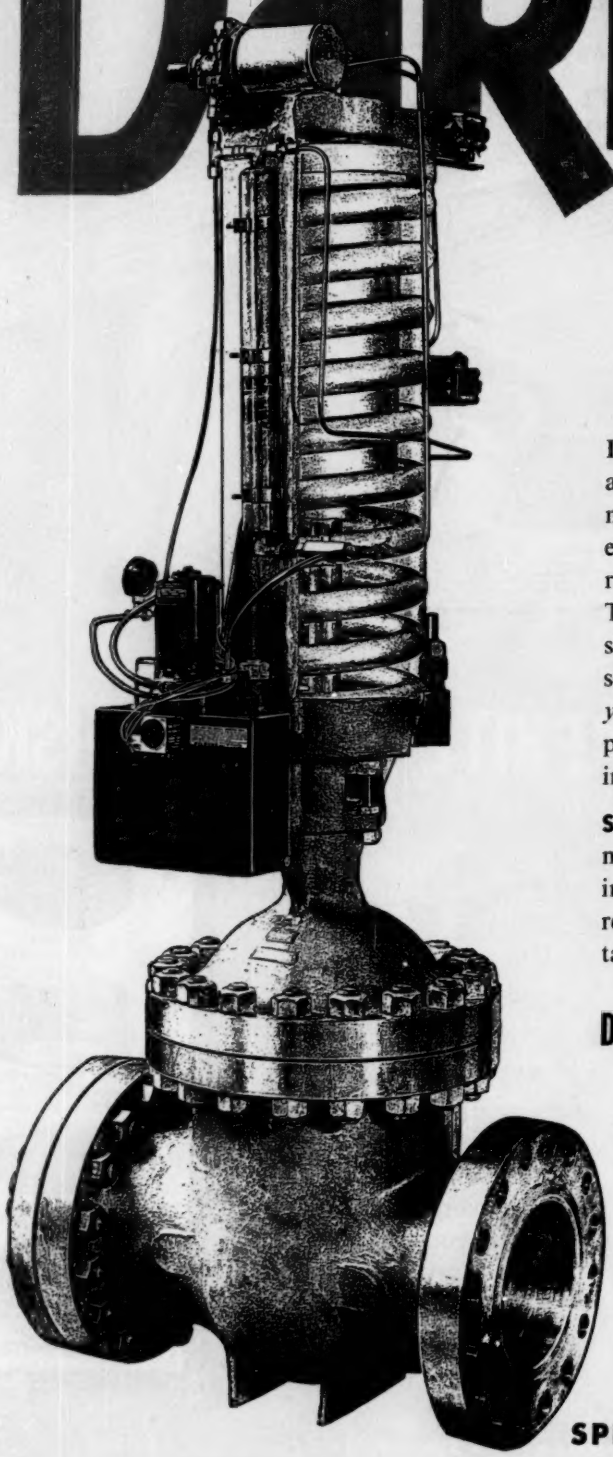
PRODUCERS OF BETTER PROCESSING EQUIPMENT FROM IMPERVIOUS GRAPHITE

Cubic, Tube and Shell, Cross-Bore, Parallel and Modular Heat Exchangers; Immersion Plate Heaters; Cascade Coolers; HCl Absorbers and Plants; Towers; Centrifugal Pumps; Ball, Control, Drain, Angle, and Diaphragm Valves; Rupture Disks; Pipe and Fittings; Crucibles; Thermowells.

Write for Bulletin 315-2

YOU CAN DEPEND ON

Darling



Darling special stainless steel gate valves are meeting the most precise demands of nuclear services. They are used in power generation installations and for flow control of radioactive fluids.

These special-purpose valves have the exclusive benefit of our revolving double disc parallel seat wedge construction feature. That's why *you can depend on Darling* steel gate valves for positive sealing and continuous ease of opening and closing.

SPECIAL ENGINEERING SERVICE. Darling engineers are ready to work with you in designing special valves to meet unusual service requirements. Write, wire or phone for detailed information.

DARLING VALVE & MANUFACTURING CO.

Williamsport 3, Pa.

Sandilands Valve Manufacturing Company, Ltd., Galt 19, Ontario, Canada.
Vannes Darling-France, 23 rue du Commandant Mouchotte, St. Mandé, France.

TRADE DARLING MARK

GATE • BUTTERFLY • CHECK
SPECIAL VALVES • FIRE HYDRANTS

New VARSOL®
For Long Lasting Sweetness!

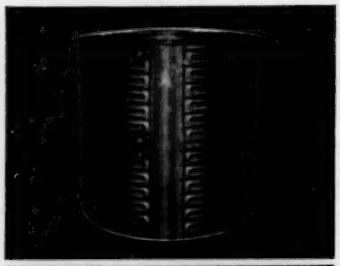
"Why the enthusiasm? Because users of new, improved Varsol find that it keeps its long lasting sweetness after numerous processings or long storage periods. A unique hydrofining process, developed by Esso Research, makes possible this major solvent development. Quality controlled Varsol, like all Esso solvents, reaches your plant fresh, uniform and on schedule from modern, conveniently located storage terminals. For further information or expert technical assistance call your Esso Representative or write to us at 15 West 51st St., N.Y. 19, N.Y. (And tell 'em Nosey sent you!)" *Nosey*

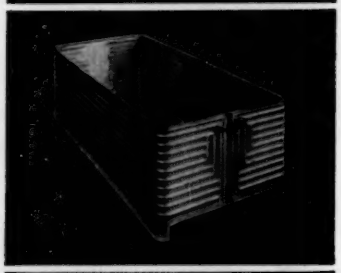
ESSO STANDARD, DIVISION OF
HUMBLE OIL & REFINING COMPANY ESSO

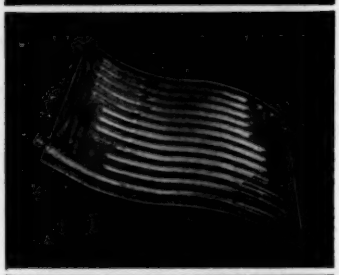
PLATECOIL®

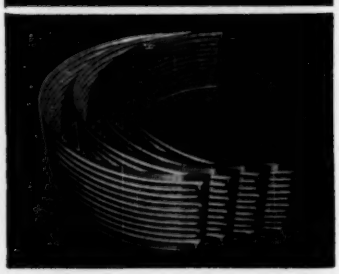
"STANDARD" STYLES OR SPECIALLY FORMED AND FABRICATED

=a SOLUTION









TO DIFFICULT HEAT TRANSFER PROBLEMS

Now you can apply the engineering, installation, operational and maintenance advantages of PLATECOIL to more tank and process heating and cooling problems than ever before. Standard units with exclusive "MULTI-ZONE" pass design for faster heat-up and temperature recovery or serpentine pass arrangement satisfy many requirements. These "standard" styles, available in a wide variety of sizes can be factory-fabricated into banks to fit the application. PLATECOIL can be formed and rolled to specified diameters or even fabricated to form tank walls.

PLATECOIL provides a "packaged" answer to many heat transfer problems, avoiding costly engineering and fabricating of pipe coils. Units are easy to install and maintain—with simple connections, light weight, and streamlined surfaces. High heat transfer capacity permits compact, space-saving units.

Both "standard" and specially built PLATECOIL are available in mild steel, stainless steel, Inconel, Monel, Ni-O-nel, Hastelloy B, C and F, Nickel and other weldable materials. Operating pressures up to 250 psig. Safety factor—5 to 1. Double embossed or one side flat. Complete engineering data and assistance available.

"PLATECOIL" CAN BE FURNISHED TO COMPLY WITH ASME CODE

Ask for Bulletin P61.

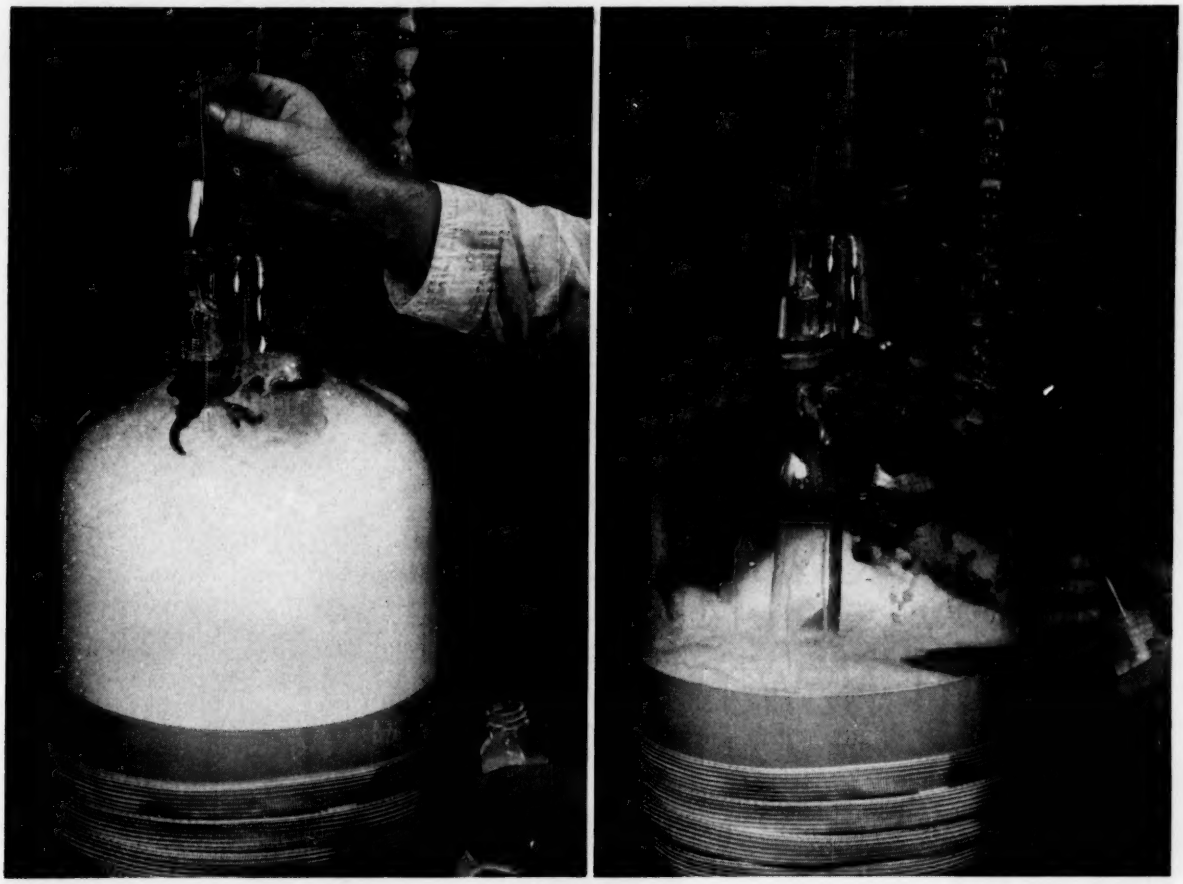
Tranter Manufacturing, Inc.

LANSING 9, MICHIGAN

PLATECOIL® DIVISION

SILICONE NEWS from Dow Corning

See How Foam Robs You



Silicones stop foam; help you operate at maximum capacity

Why accept foam as a necessary evil, when you can control it effectively and economically with Dow Corning Silicones? Amazingly effective in trace quantities, these silicone antifoamers enable you to utilize capacity now taken up by foam . . . help speed processing . . . prevent spill-overs . . . reduce fire hazards . . . cut maintenance costs.

Serving Every Industry. Dow Corning job-proved silicone defoamers and antifoamers neither alter nor adulterate products or processes. And they're effective against even the most violent and persistent foamers. Typical applications include processing of adhesives, chemicals, petroleum, asphalt, paper, paints, textile and drugs; also useful in metalworking and laboratory work. In food processing, the use of food grade Dow Corning antifoamers at designated levels is sanctioned by FDA.

Easy to Use. You don't need extra equipment or preparation time when you use Dow Corning Silicones to control foam. Our product development group has formulated different types to be most adaptable to different systems . . . to help you rid your process or product of foam problems effectively, economically.

Free Sample. Here's your chance to see how Dow Corning Silicones can work for you. Tell us your foam problem and type of system—oil, aqueous, nonaqueous, food product or other. A generous trial sample of the silicone defoamer most suitable for your process will be sent by return mail. Write Dept. 2418.

"ABC's of Defoaming" — new 8-page brochure gives full data. Write today for free copy. Address Dept. 2418.

first in silicones

Dow Corning CORPORATION
MIDLAND, MICHIGAN

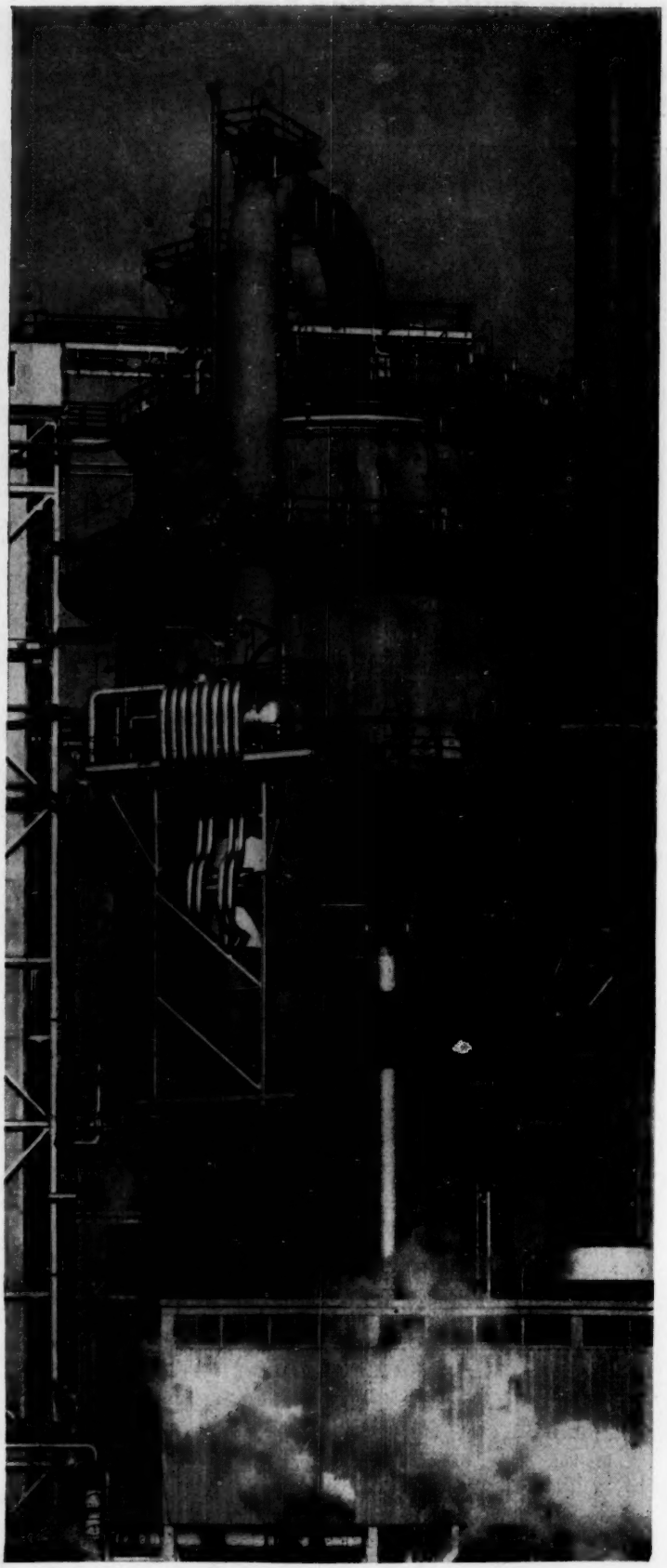
ATLANTA BOSTON CHICAGO CLEVELAND DALLAS LOS ANGELES NEW YORK WASHINGTON, D. C.

BUILT TO TOWERING PROPORTIONS BY NEWPORT NEWS

Newport News has all of the specialized skills and equipment needed to fabricate heavy process equipment used by the petrochemical industry. For example, Newport News can roll plate up to 5 inches in thickness and weld almost any type of metal, utilizing the most modern equipment and techniques.

To match its modern production equipment, Newport News has expert staffs of engineers and technicians backed up by thousands of skilled workmen who use these facilities with the highest degree of craftsmanship.

If you are considering the construction of pressure vessels, vacuum tanks, towers, reactors or related equipment, you'll find it to your advantage to get a bid from Newport News.



This 168' 9" Orthoflow converter, built by Newport News for Tidewater Oil Company's Delaware Refinery, south of Wilmington, Delaware, is the largest of its kind ever built.

Newport News
SHIPBUILDING AND DRY DOCK CO.
NEWPORT NEWS, VIRGINIA

Today's most Compact, Variable Speed Package Drive for constant H.P. and constant Torque loads

New space-saving Cleveland motorized Speed Variator

Now, for either OEM applications or to modernize existing machines and equipment, these versatile, precision-engineered Speed Variators can be used in place of larger variable speed drive units and their connecting electrical drives. If there's room for a motor —an equally sized Cleveland will usually fit in the space.

Here's the complete Motorized Speed Variator story:

- Requires only slightly more space than equally rated standard electric motor
- Provides variable output speeds over 9:1 and 6:1 ranges
- A complete line featuring 5 sizes from ⅓ to 15 HP
- Integral "pancake" style AC radial air gap motors conforming to NEMA design "B" specification
- Provides speed holding accuracy up to 0.1% with uniform loading
- Output speeds smoothly and easily adjusted while operating under load

Variator is a true torque converter—provides high torque at low speeds for constant HP applications.

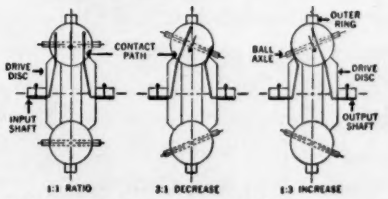
Utilizing the component you wish driven, Cleveland will design and build a complete compact pre-aligned and tested Speed Variator drive assembly mounted on a suitable base plate.

New Motorized Variators offer the ultimate in control versatility. They can be engineered for either manual, electrical or pneumatic operation.

For complete engineering information on the New Cleveland Motorized Speed Variator, write for free, illustrated bulletin Number 275 or contact your Cleveland representative today.

How The Speed Variator Works

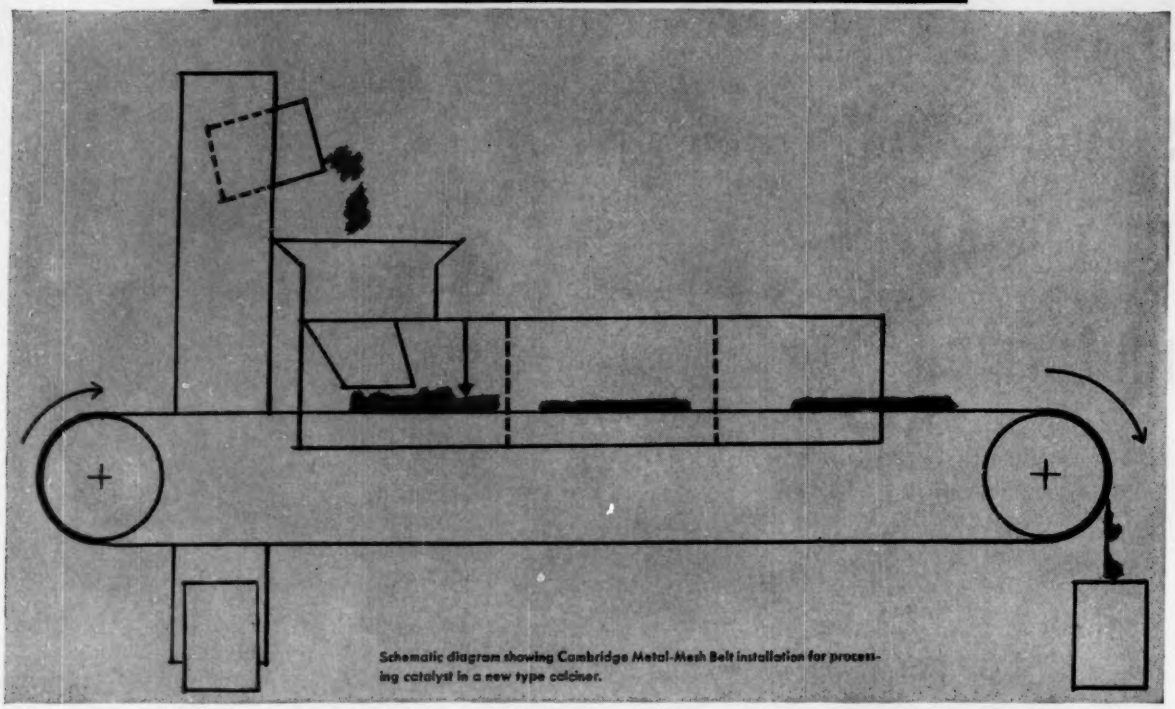
Power is transmitted through input shaft to a beveled drive disc in contact with axle-mounted alloy steel drive balls. Input shaft rotation causes balls to rotate about their axles. Power is then transmitted from all rotating balls to output shaft by similar ball-disc contact on the output side. Output speed is determined by relative lengths of contact paths on input and output sides of the balls. By tilting both axles and balls, relative lengths of the two contact paths are varied to give increasing or decreasing ratios as shown on sketches.



Cleveland Worm & Gear Division
Eaton Manufacturing Company
3288 East 80th Street • Cleveland 4, Ohio

CLEVELAND VARIATOR

Cambridge Type 316 Stainless Metal-Mesh Belt



Schematic diagram showing Cambridge Metal-Mesh Belt installation for processing catalyst in a new type calciner.

BEATS CORROSION PROBLEMS TO MAKE CONTINUOUS CHEMICAL PROCESSING MORE PROFITABLE

A Cambridge Belt works two ways to beat the tough operating problems that are usually a part of continuous chemical processing. First, careful, quality workmanship means a belt that lasts longer, gives fewer maintenance problems. Second, proper alloy selection can lick problems like corrosion or abrasion. Take corrosion for instance. The Cambridge Type 316 Stainless Steel Metal-Mesh Belt resists such corrosives as acetic acid vapors, chlorides, bromides and iodides. And, it has extra strength at high temperatures.

There is a complete line of Cambridge Belts in special and standard metals and alloys to meet your specific requirements—custom-built in any weave to insure the most efficient processing.

Experienced Cambridge Field Engineers—experts in their field—are available to discuss your needs and help you select the belt best suited to your operations. Or, they can offer you sound advice on the installation, operation and maintenance of your Cambridge Belts. Talk to your Cambridge man soon. He's listed in the Yellow Pages under "Belting, Mechanical". Or, write for free 130-page reference manual.

The Cambridge Wire Cloth Co.

DEPARTMENT G • CAMBRIDGE 6, MD.

Manufacturers of Metal-Mesh Conveyor Belts, Flat Wire Conveyor Belts, Wire Cloth, Wire Cloth Fabrications, Gripper® Metal-Mesh Slings

BONUS LIFE
BONUS PROTECTION

from the Boiler Capital of the World

TITUSVILLE WTP
FROM THE BOILER CAPITAL OF THE WORLD

• BONUS LIFE means longer life and less refractory maintenance made possible by Titusville's unique WTP design featuring *65% Black Surface Tube Area coverage on rear wall.*

Titusville's increased black surface tube area means less refractory maintenance through longer refractory life (less down-time for replacement) and a faster steamer.

• BONUS PROTECTION provided by Titusville WTP's *double casing design* solves the corrosive product problem.

Most water tube steam generators operate intermittently. When dew point is approached at low fire condition, corrosive product can form quickly in single casing boilers.

Titusville WTP's double casing design (with insulation between) reduces temperature differential. Result: formation of corrosive product almost entirely eliminated for many times more casing life.

THE TITUSVILLE IRON WORKS COMPANY
TITUSVILLE, PENNSYLVANIA

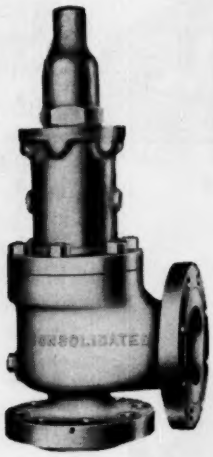
Division of Struthers Wells Corporation

Specify Titusville WTP ... the industry's fastest selling boiler

Selected exclusive sales territories available

top

CONSOLIDATED SAFETY RELIEF VALVES have a special "O" Ring Seat Seal that stops leakage completely



Consolidated Safety Relief Valves are available in both Standard and Balanced Bellows design for extreme corrosive applications.

tightness

The Seal is a resilient ring set in the valve disc. It maintains no-leak tightness by contact with a specially curved seating surface on the valve nozzle, yet does not carry the seat load imposed by the valve spring.

Tightness is maintained at operating pressures far closer to set pressure than with metal-to-metal seats alone. Tight closure is as efficient after "simmer" as on normal blowdown. Piping strains are absorbed far better by the resilient seal than all-metal seating. If the tough seal is ruined by entrained abrasives, replacement is easy. Seals are available in materials that resist corrosive fluids. Maintenance costs are greatly reduced.

Standard Consolidated Safety Relief Valves have an eductor tube that removes pressure from the closed bonnet. Only the spring controls valve action. You get guaranteed capacity ratings and highest dependability—absolute protection for personnel and equipment. Additionally, there is the economy of converting the Standard valve to the Balanced Bellows type in your own shop. Get complete details. Write for Bulletin 1940.

MANNING MAXWELL & MOORE INC. M&M TRADE MARK

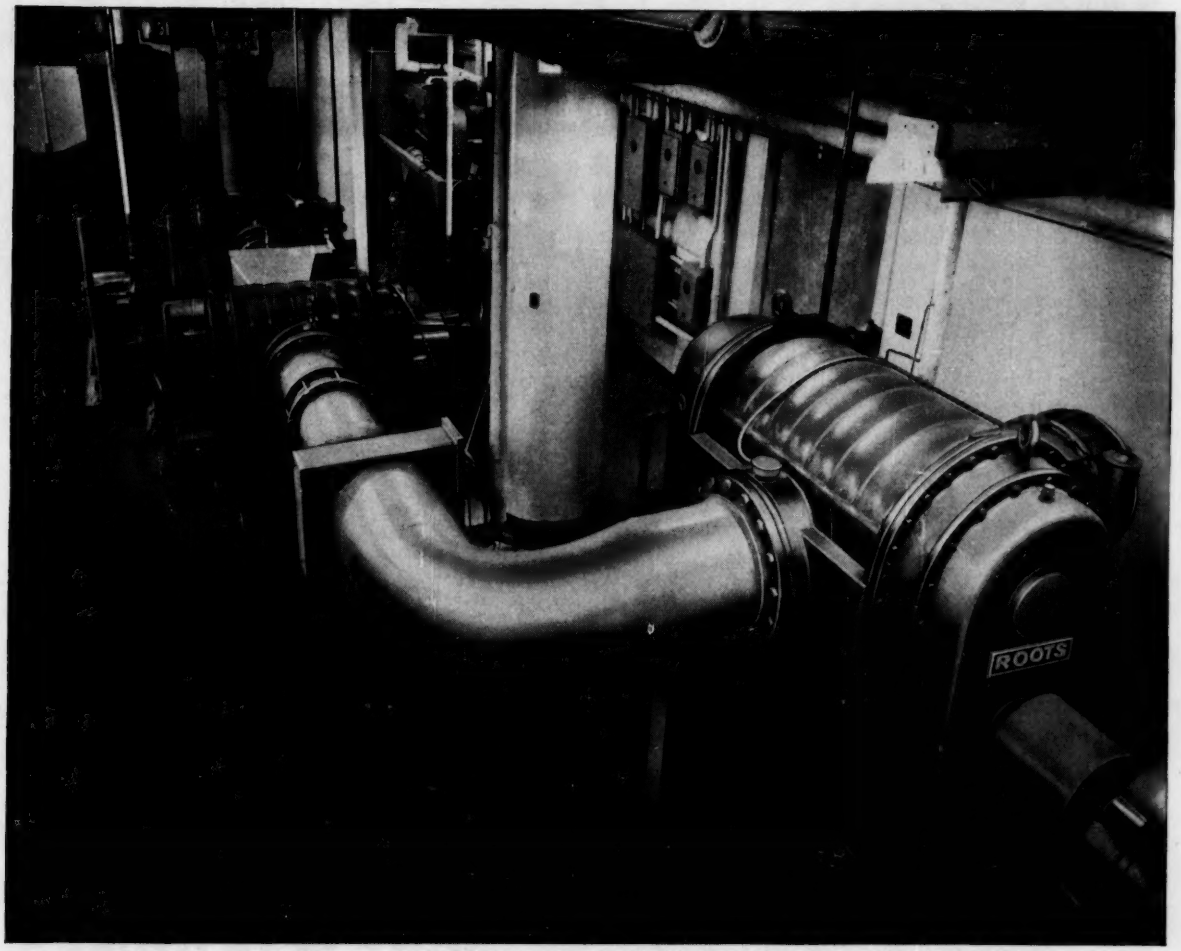
CONSOLIDATED SAFETY RELIEF VALVES

A product of

MANNING, MAXWELL & MOORE, INC.

Valve Division • Tulsa, Oklahoma

Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario
Latin America: Export Division, Chrysler Building, New York, N. Y.
Europe: Manning, Maxwell & Moore, S. A., Fribourg, Switzerland



Here, three Roots* Boosters are cascaded with a mechanical forepump to simulate altitudes to 155,000 feet (0.92 mm Hg absolute) with an air flow of 1 lb./min., in an environmental test chamber.

Here is a new way to reduce equipment costs and increase efficiency in your high-vacuum processing or environmental system. Roots* Vacuum Boosters are ideal for handling large volumes to 35,000 CFM at absolute pressures as low as one micron.

You save in the number of units required. Select the booster specifically fitted to your requirements; yet, because the Roots Booster has the flattest pumping speed curve of any booster, it is useful over a wider range of operating pressures.

Because operation is practically vibrationless, the booster can be connected directly to the chamber. No valves or by-passes are required in the high-vacuum series; a Roots Booster can windmill in the line until its operating pressure is reached.

Roots Booster operation is efficient, cool, and quiet. Usual operation is at 10-15 compression ratio, and volumetric efficiency is as high as 93%. Vacuum-tight seals proved at a fraction of a micron prevent any leakage, and blank-off pressure is 0.5 micron or lower. There is no bumping or vapor backstreaming, and Roots Boosters easily handle bursts of gas which may result from some processes.

Rugged construction and thorough engineering by the originators of Roots Positive Pressure Blowers assure long, trouble-free life without expensive service interruptions and repairs. Most units are suitable for operation with a differential pressure of more than 7 PSI.

If you need high-vacuum with high throughput in a new or existing system, a single booster or a cascaded system, find out all the advantages of using Roots High-Vacuum Boosters. Forty-five sizes (pumping speeds from 200 CFM to 35,000 CFM) are available. Ask your vacuum equipment supplier or write Roots-Connersville.

ROOTS* is a registered trademark of Roots-Connersville Blower

ROOTS-CONNERSVILLE BLOWER DIVISION • 900 W. MOUNT ST., CONNERSVILLE, INDIANA
In Canada—Roots-Connersville Blower (Canada), Ltd. • 212 King Street, West, Toronto

CLARK® Engines, Compressors, Gas Turbines

Working together in allied industries . . .

PODBIELNIAK Centrifugal Contactors, Distillation Apparatus, Instrumentation

ROOTS

DRESSER INDUSTRIES INC.

OIL • GAS • CHEMICAL
ELECTRONIC • INDUSTRIAL

LOAD MOLTEN SULPHUR, ASPHALT IN LESS TIME AND GREATER SAFETY

CHIKSAN STEAM JACKETED JOINTS

AND JACKETED LOADING ARMS

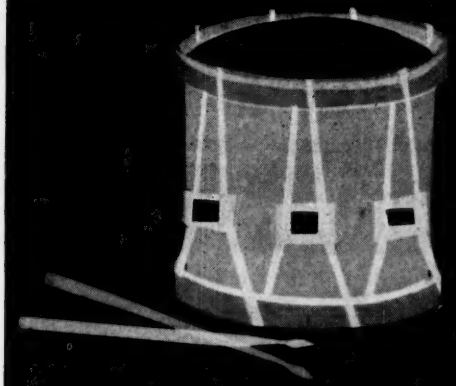
Consider the advantages a Chiksan steam jacketed joint offers you. It is an effective long lasting product backed by over 10 years of proven-in-use service. It is available to you in a complete range of sizes from 2″ thru 12″ pipe size. It can be equipped with any one of a number of packing units tailoring the joint to your specific service. In addition to sulphur and asphalt, these joints and arms are equally adept at handling viscous oils, napthalene and heavy tars. There is another plus in the Chiksan steam jacketed joint—the many practical years of Chiksan know-how in designing installations. These recommendations teamed with Chiksan equipment are your assurance of a facility providing maximum flow-thru with greatest safety. For more specific details on steam jacketed joints and arms, write Chiksan.

CHIKSAN

fmc

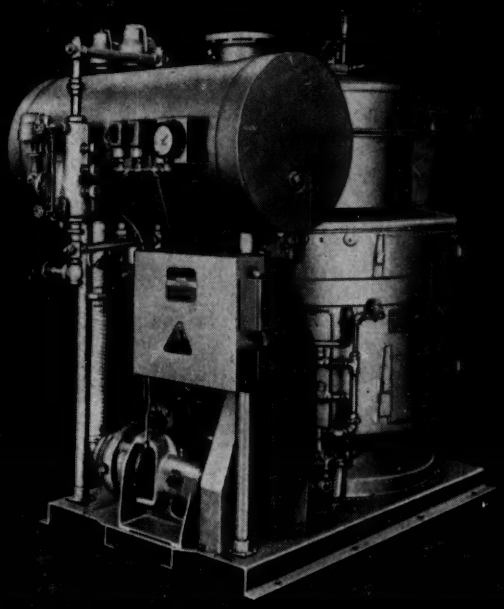
#61-63

CHIKSAN COMPANY—General Offices: Brea, California • Well Equipment Mfg. Corp. Division (Weco Unions, Hamer Valves) • Chiksan International • Chiksan of Canada Ltd.
Offices and Representatives in Principal Cities of the World



THIS DRUM IS FOR MUSIC...

THIS DRUM IS FOR POWER!



Vapor DRUM MODULĀTIC water tube boiler

World's Most Compact Heat and Power Package

200 BHP in only 40 sq. ft.

This pocket-sized power package hits the right note with engineers everywhere. It's compact, efficient...takes only 5' x 8' of floor space. Costs less to install...delivered completely assembled, wired, pre-tested; needs no special foundation, fits through plant doors, can be installed in any unused corner or aisle. Costs less to operate...modulating controls produce steam only "on demand," save fuel. Full steam pressure in 5 minutes from cold start.

Send for free literature:

Ends early-morning shift to fire-up. Fully automatic, push-button operation. Most flexible...multiple-unit installations meet widely-varying, or peak-load steam requirements. Single, coordinating control cuts individual units on or off as steam demand varies. Easiest to maintain...all parts are readily accessible. Burns oil, gas, or both fuels. Meets all codes.

Complete Line of Boilers. 20 to 200 hp; 0-15, 5-150 psi steam pressure; 670,000 to 6,690,000 btu/hr.

VAPOR®

Our requirements are:

BHP REQUIRED_____

SAFETY VALVE SETTING_____

MINIMUM STEAM LOAD_____

MAX. STEAM LOAD_____

STEAM PRESSURE_____

TYPE OF FUEL_____

VAPOR HEATING CORPORATION, Dept. 2-F
80 E. Jackson Blvd., Chicago 4, Illinois

Please rush me your free bulletins on Modulātic Water Tube Boilers.

NAME_____

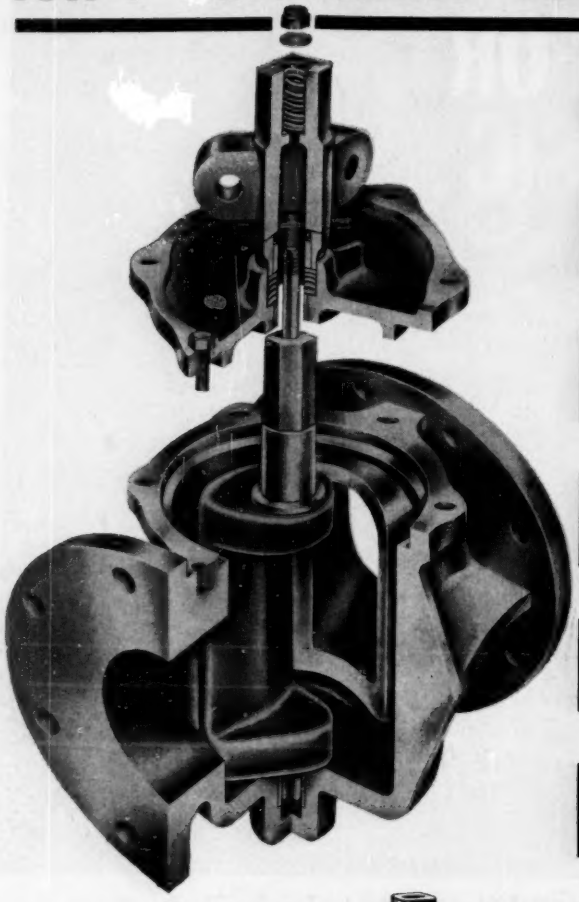
TITLE_____

FIRM_____

ADDRESS_____

CITY, ZONE, STATE_____

ISN'T THIS WHAT YOU WANT IN A VALVE?



Positive leak-free shut-off

...On any flow from air to solid

Easy, smooth operation

...Regardless of Cycle-Frequency

No lubrication or fuss

...Virtually no maintenance needed

No stem freeze-up or bind

...Plus Replaceable Stem Packing

Resistance to corrosion

...Full range non-corrosive materials

Exceptional long life

...Prolonged performance in toughest use

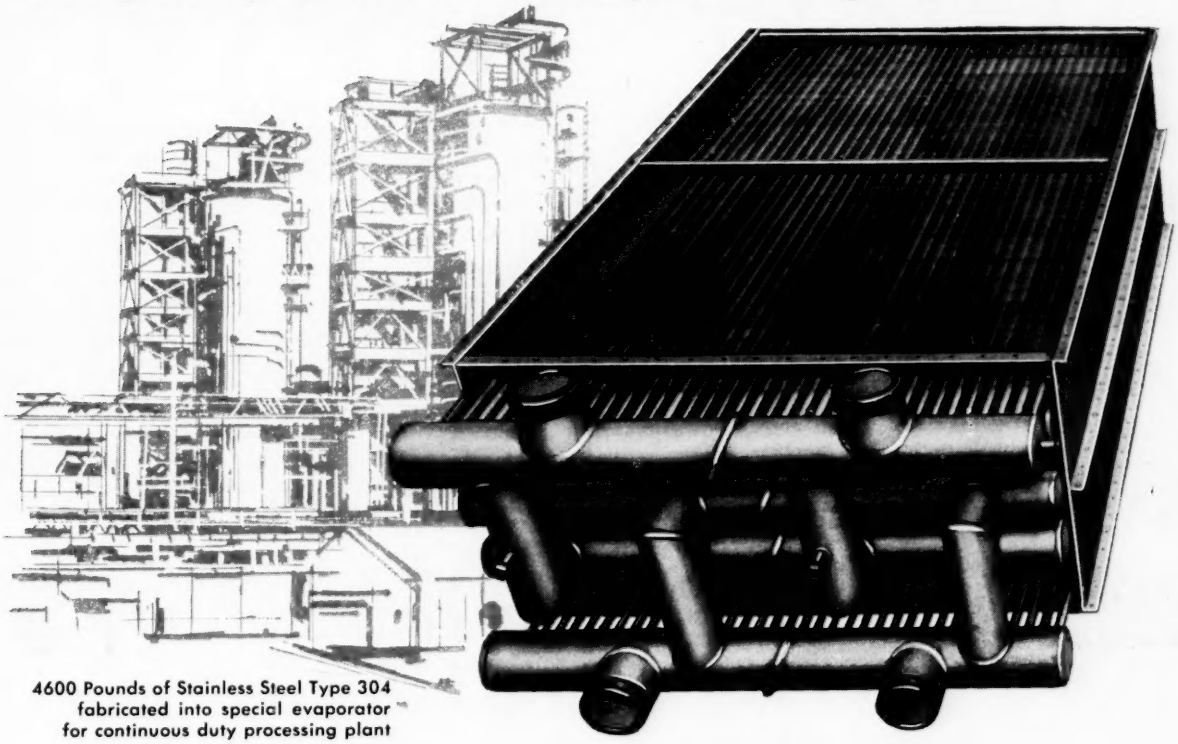
YOUR MOST USEFUL VALVES ARE **DeZURIK ECCENTRIC-ACTION PLUG VALVES**

In one chemical plant after the other, DeZURIK VALVES keep proving themselves the most dependable, most complete valves for almost every type of service. Their eccentric-action is the most trouble-free design ever developed; resilient-faced plug delivers cushioned, dead-tight closure on every flow, every time. No lubrication, yet absolutely free and easy in its quarter-turn rotary operation. Available in complete selection of body materials and plug facings, manual or automated, sizes from ½" thru 24". Low in initial cost, lowest in maintenance cost.

CATALOG ON REQUEST.

DeZURIK CORPORATION
SARTELL, MINNESOTA

Designed by Marlo to Your Performance Specifications



4600 Pounds of Stainless Steel Type 304 fabricated into special evaporator for continuous duty processing plant

Stainless Steel Extended Surface Heat Exchanger

Typical of the kind of special custom fabrication produced by Marlo know-how for the process industries, this unit has these specifications:

Duty: 2,000,000 B.T.U. per hour
outside surface: 10,700 square feet
inside surface: 830 square feet
surface ratio: 12.9 to 1

size:
length: 100 inches
width: 60 inches
height: 30 inches
dry weight: 4600 pounds

materials:
tubing: ¾" O.D. — 304 stainless steel
headers: 5" O.D. — 304 stainless steel
fins: 0.010" — 304 stainless steel
frame: 0.190" — 304 stainless steel
working pressure: 400 psi

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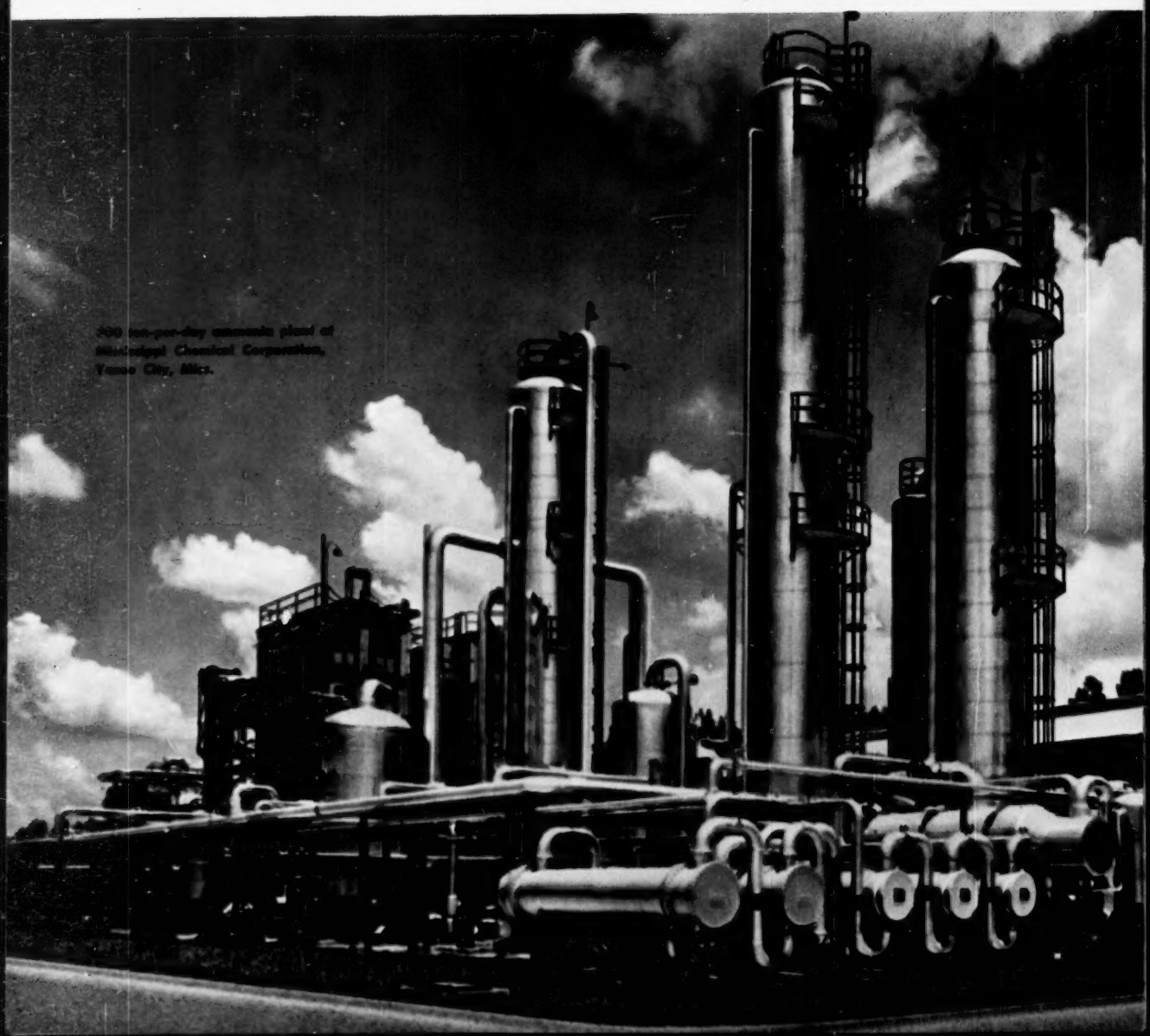

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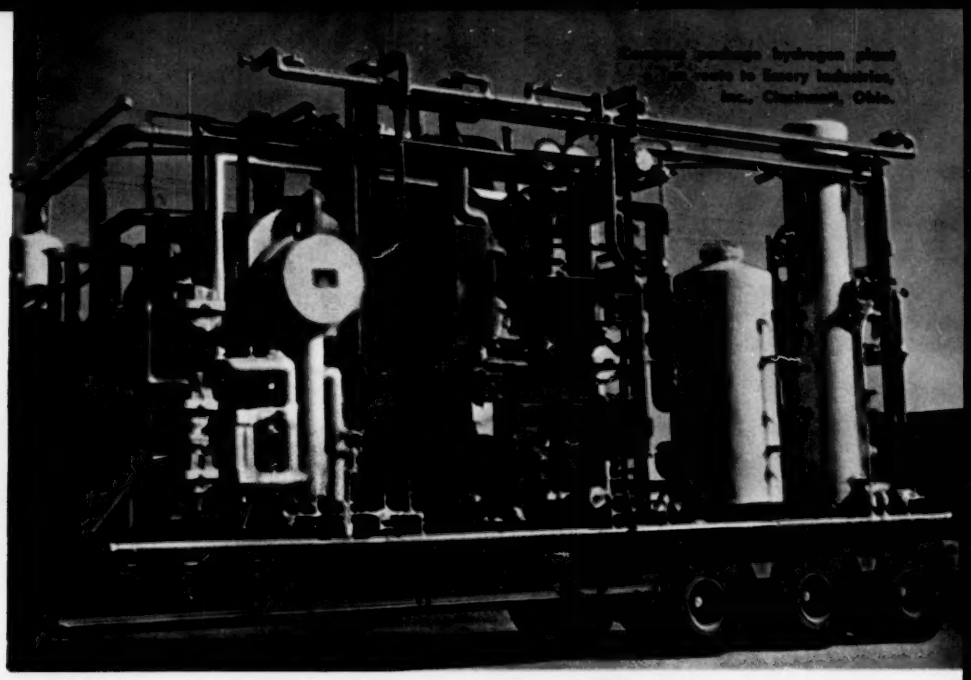

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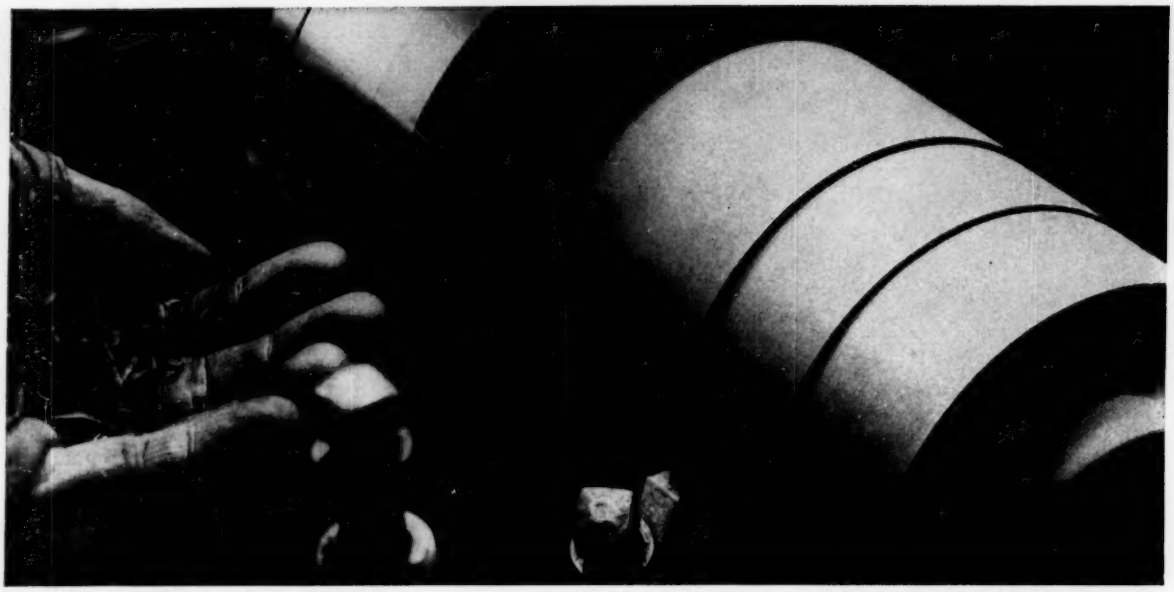

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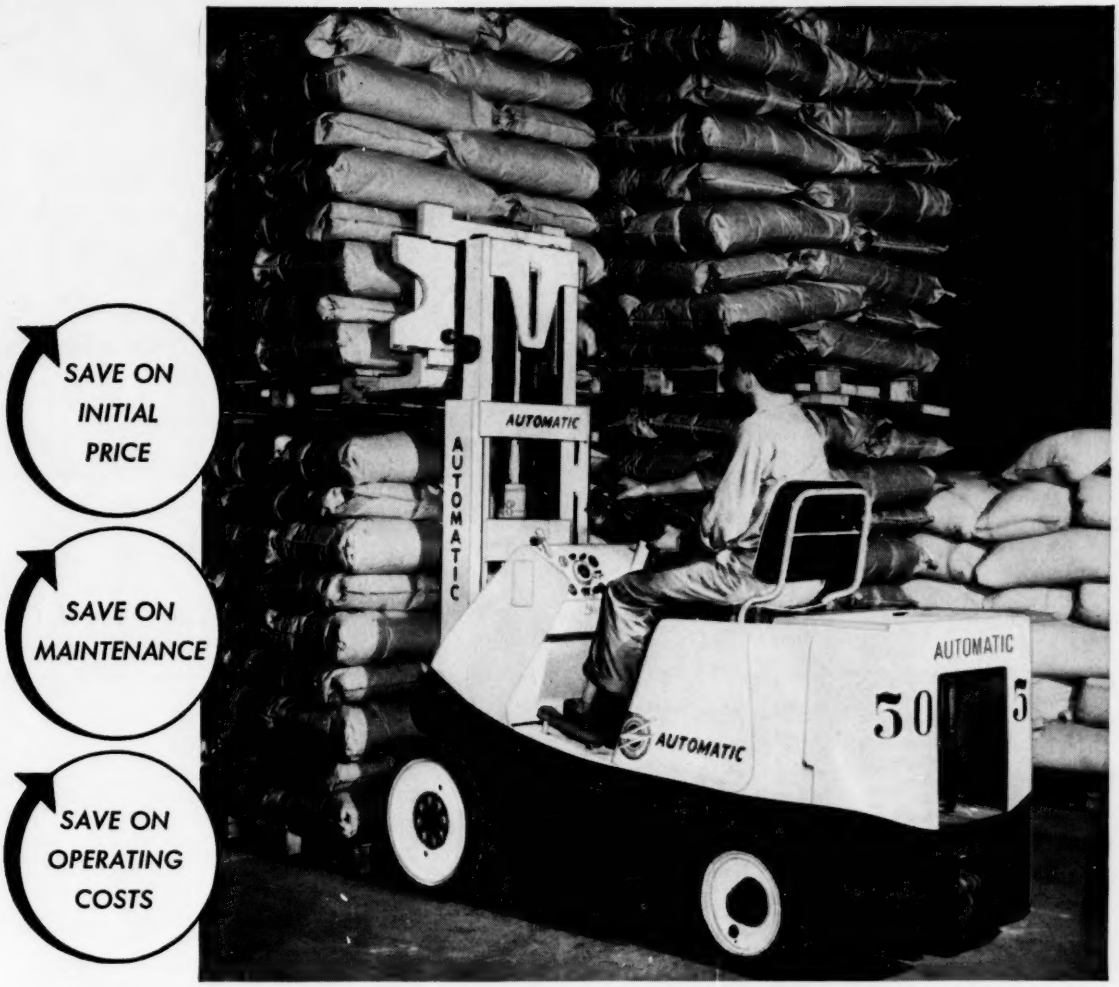

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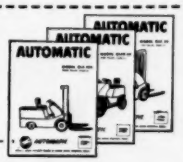

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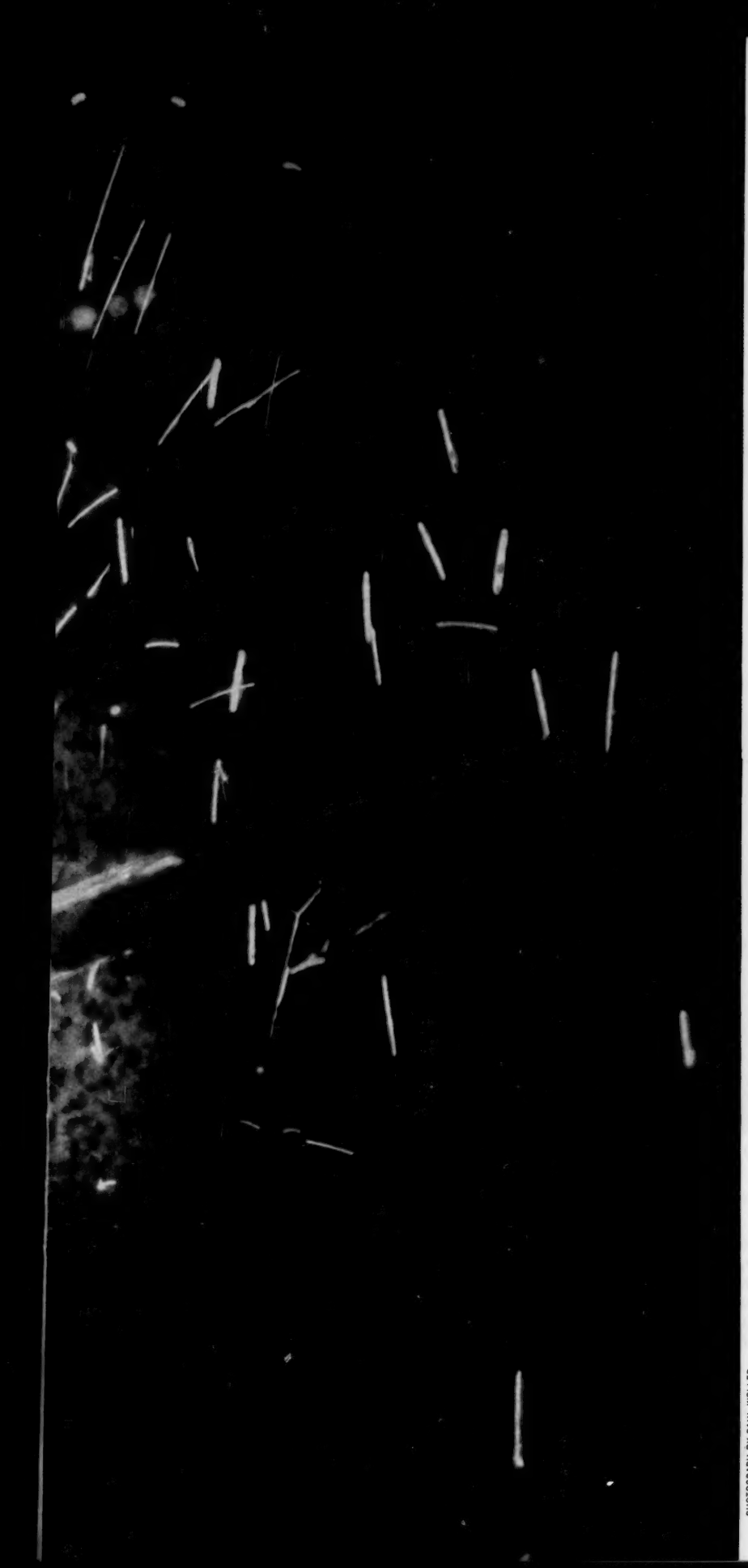

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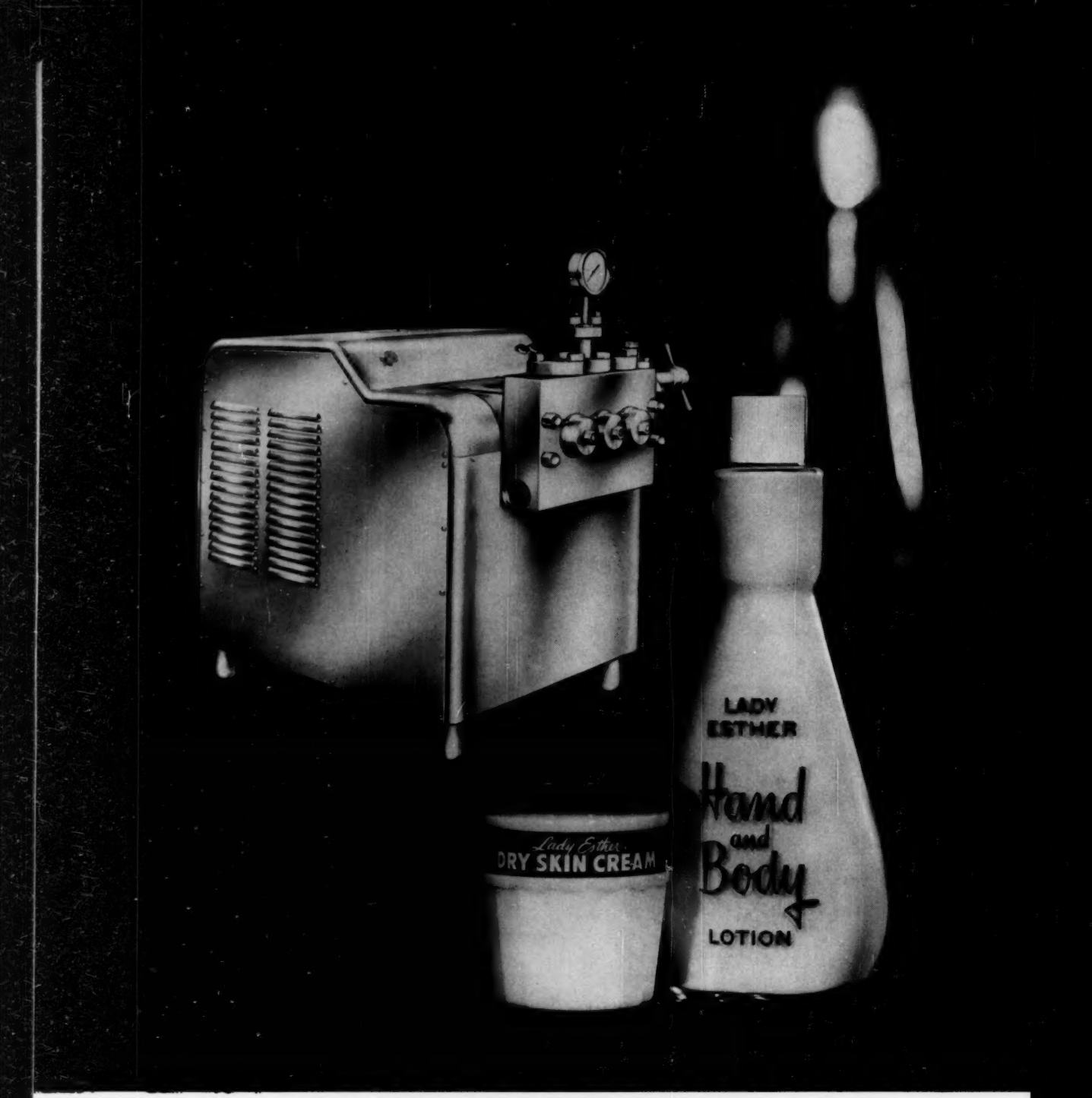

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National Carbon representatives expand your engineering force

N. R. SWENSEN
Sales Engineer

Mr. Swensen is National Carbon's field sales engineer for chemical products in the State of Ohio, with headquarters in Cleveland.

As a member of National Carbon's application engineering group, he was active in the design and development of chemical processing equipment, particularly entrainment separators and hydrochloric acid absorption systems.

Mr. Swensen is a graduate of Michigan State University. He joined National Carbon Company in 1957.

Carbon Saddle Packing withstands abrupt temperature changes without spalling

Developed jointly by National Carbon Company and The United States Stoneware Company, carbon "INTALOX" saddle packing has a broad range of chemical applications. These saddles are recommended for hot alkalis, mixtures of hydrofluoric and sulphuric acids, hydrofluoric acid, and phosphoric acid—uses where chemical-resistant ceramics would be unsuitable. The unique carbon shape assures maximum contact surface between liquid and gas or between liquid and liquid. For data, write The United States Stoneware Company, 60 East 42nd Street, New York 17, N. Y.

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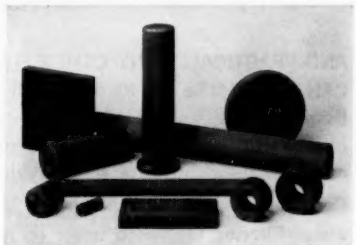

In recent years, porous carbon has also been used as insulation for high-temperature furnaces and reactors, where resistance to corrosion and dimensional stability at high temperatures are essential.

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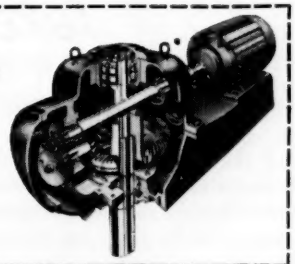

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Top news stories and what they mean to CPI technical decision-makers

Chementator

Jet engine stands up well in service on pipeline compressor

Cooper-Bessemer's experiment to see if an aircraft jet engine can be made to drive conventional compressors (*Chem. Eng.*, Dec. 26, 1960, p. 42) has been judged a qualified success after 3,000 hr. of operation.

In service at a pipeline compressor station of Columbia Gulf Transmission Co., at Clementsville, Ky., the unit consists of a Pratt & Whitney J-57 engine coupled to a heavy-duty two-stage power turbine. Unit develops 10,500 hp. at 5,000 rpm., has achieved the expected 25% thermal efficiency.

One big advantage of the jet engine as a prime mover is the speed with which it can be replaced for maintenance checkups. This was proved recently when a piece of the diffuser liner (which channels gas from the jet to the turbine) broke off and entered the turbine. One turbine blade was lost, shutting down the unit automatically.

While the turbine was down, the jet engine was pulled out and sent back to Pratt & Whitney for overhaul. The engine was found to be in good shape. Engine replacement time was only 4-6 hr., compared with several days for conventional compressor installation turnaround.

Based on operation to date, Cooper-Bessemer feels that the J-57 will have no trouble in attaining the target of 8,000 hr. of operation without maintenance.

The company estimates that a 10,500-hp.. engine-compressor combination should cost about $700,000-$1 million installed. It is now offering a similar unit equipped with a smaller 2,500-hp. engine.

Thermal hydrodealkylation route to aromatics picks up extra support

Two more companies recently announced interest in hydrodealkylation as a means to produce petrochemical naphthalene and benzene. And both of these firms are backing thermal rather than catalytic processes.

Gulf Oil says that it has developed its own version (THD) of thermal hydrodealkylation. Main attraction of the process: benzene yields ranging from 93 to 97% of theoretical, based on toluene feed. Reactor system is said to be coke-free; it is believed to operate around 1,200-1,400 F. and 800 psi. Gulf says that negotiations are currently under way for the construction of two plants utilizing this flowsheet.

Esso Research & Engineering, another thermal proponent, has entered a cross-licensing agreement with Hydrocarbon Research and Atlantic Refining for the HDA process (*Chementator*, Mar. 20, p. 75). Under the agreement, Esso receives all the hydrodealkylation know-how of HRI and Atlantic, while HDA licensees will get rights to Esso's patents and process techniques.

Thermal route is claimed to be simpler and more economic than catalytic processes such as UOP's Hydeal and Houdry's Detol. On the other hand, catalytic processes operate at lower temperatures (1,000-1,200 F.), easing the materials of construction problem. It may be a while, however, before enough data are gathered for a valid comparsion, since only one thermal plant (an HDA unit in Argentina) has been announced.

Petronaphthalene may spawn a new breed of polyester fiber and film

Underscoring the growing prominence of naphthalene chemistry, Sun Oil tells *CE* that it has just stepped up operations at its Marcus Hook, Pa., pilot plant to turn out over 100 lb./day of the dimethyl ester of naphthalene-2,6-dicarboxylic acid. The firm is now supplying this material to polyester fiber and film makers for evaulation as a successor to dimethyl terephthalate (DMT).

Sun's dimethyl ester is made from 2,6-dimethyl naphthalene, which it will be able to

Heavy-duty junction boxes have to be more than mere splice points. That's why the Crouse-Hinds WJBF floor-Condulet is built to resist wash-down water, atmospheric moisture, dust and alkaline atmospheres – conditions that will reduce an ordinary junction to fireworks long before the Fourth of July. Hot-dip galvanized, cast Feraloy construction does the job.

And you can get the same neoprene-gasketed moisture protection in the surface-mounted raintight Crouse-Hinds WJB Condulet. Both types are available in cast aluminum, sold at the same price as Feraloy.

28 sizes of each type are available, ranging from 4"x4"x4" to 24"x24"x12", with or without mounting feet. The number and size of conduit entrances can be specified or Condulets can be drilled and tapped in the field. *For more information check your Crouse-Hinds Distributor.*

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produce via solvent extraction of the gas-oil feedstock to the 100-million-lb./yr. naphthalene plant the firm is building at Toledo, Ohio. If markets develop, Sun has a potential for making up to 40 million lb./yr. at Toledo, and additional quantities at its Marcus Hook refinery.

Collier Carbon & Chemical has already announced interest in these materials (*Chementator*, Apr. 17, p. 122). It could produce 25 million lb./yr. at the Delaware City, Del., naphthalene plant it is building as a joint venture with Tidewater Oil.

Enthusiasm for this dimethyl ester in fibers stems from its high (about 260 F.) second-order transition point, making a fiber that will be wrinkle-resistant in the hottest wash water. (Present DMT polyesters have transition points close to that of 180 F. wash water.)

Price for DMT is now around 35¢/lb. Projected initial cost for the new high-temperature ester is about 45¢/lb., says Sun.

The firm is also producing small quantities of the 2,7-dicarboxylic acid. This is less symmetrical than the 2,6-isomer, and can be used in combination with the latter to make a tough, flexible polyester film.

The difficult oxidation of the dimethyl naphthalene is accomplished by a secret Sun-owned process. Dimethyl ester is then produced by conventional acid-catalyzed techniques.

Construction of a 15-million-gal./yr. cyclohexane plant at British American Oil's Clarkson, Ont., refinery will make Canada self-sufficient in nylon raw material. Slated to be completed by late 1962, the unit will supply Du Pont of Canada's resin and yarn plant at Maitland, Ont.

New liquid-phase oxidation process produces all three phthalic acids

Capitalizing on four years of pilot-plant operation, Cowles Chemical Co., Cleveland, is teaming with Catalytic Construction Co., to offer a new process for oxidizing xylenes to phthalic acids.

Route is described only as a continuous liquid-phase catalytic process employing air oxidation. This description is similar to the Amoco liquid-phase oxidation process that employs bromine and a heavy metal as a catalyst. Cowles emphasizes, however, that it has come up with a different catalyst system.

One main selling point for the process is its flexibility. It can produce phthalic, isophthalic or terephthalic acids (from *o*-xylene, *m*-xylene and *p*-xylene respectively) in the same equipment on a blocked-out production schedule. It is designed to operate on a pure xylene feed, will not handle mixed feedstocks.

Economics data have not yet been released on the process. However, a spokesman for Catalytic says that the route has achieved yields of 1.1 lb. phthalic/lb. *o*-xylene. Highest reported yields of phthalic from vapor-phase oxidation are 0.85-0.95 lb./lb. *o*-xylene (*Chem. Eng.*, May 29, p. 48).

But Scientific Design, with experience in both liquid and vapor-phase oxidation of *o*-xylene, says that it believes that vapor-phase is the most economical route if only phthalic is desired.

Liquid-phase oxidation, however, is the only known way of producing iso- and terephthalic acids. And since all of the liquid-phase processes are tied up by the owner companies in the U. S. (e.g., Amoco and Oronite), Cowles and Catalytic seem to have the only available flowsheet for producing the entire phthalic acid family.

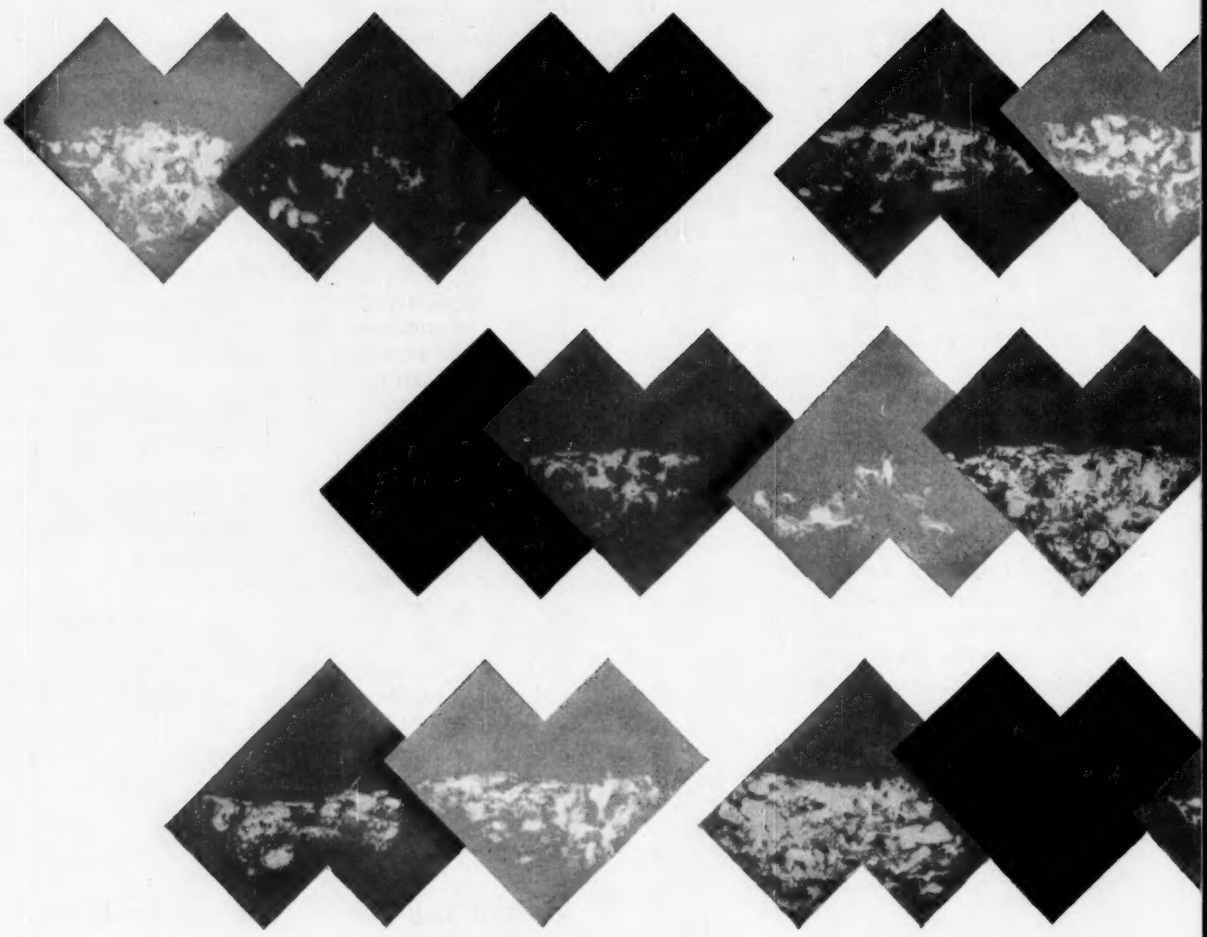
Poor-relation of the xylene family finds outlet in synthetic resins

Commercial production of resins based on the reaction of *m*-xylene and formaldehyde has started in Japan. To be used in rubber adhesives, paints, varnishes and printing inks, the resins represent a new potential for this "problem" xylene.

Though the isomer content of xylenes includes twice as much of the meta-isomer as of the ortho and para, uses for the latter two are growing more briskly. Capacity for para-xylene —used to make terephthalic acid for polyester fiber and film—is due to rise from 206 million lb. in 1960 to 314 million in 1962. Consumption of ortho-xylene—for which U. S. capacity is due to rise from 214 million lb. in 1960 to 682 million in 1961—is growing rapidly due to the product's increasing popularity in the manufacture of phthalic anhydride.

But the meta-isomer accounted for only 14% of the 47-million-gal. total demand for iso-

(Continued on page 88)



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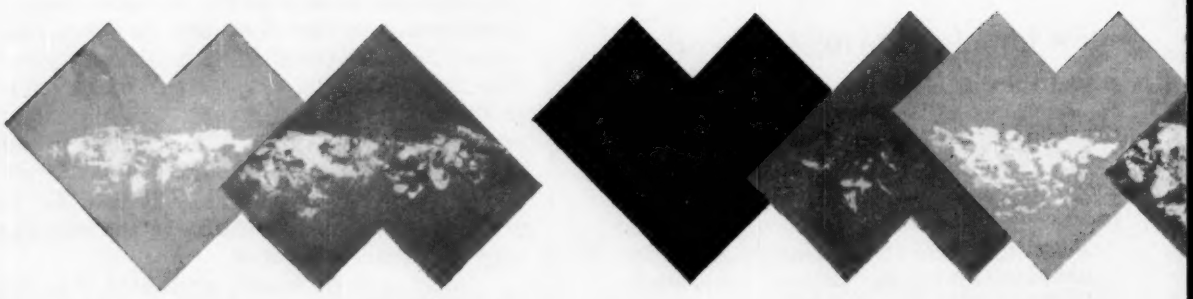

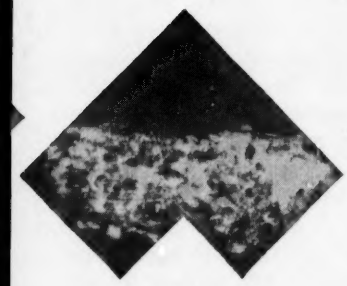

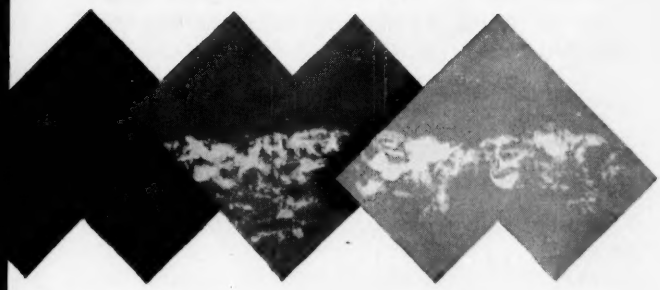

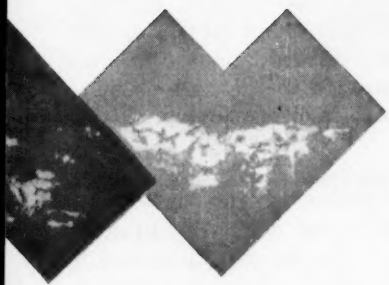

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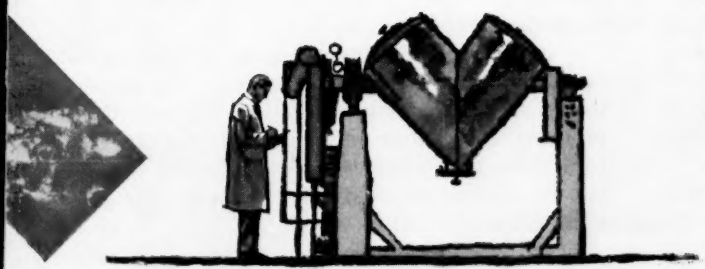

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7. *Heat sterilization of solids*
8. *Gas sterilization of solids*
9. *Chemical reaction of solids*
10. *Heating or cooling of solids*

(Many of these operations can be performed under vacuum)

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Patterson Kelley

Chemical and Process Equipment Division
126 Burson Street, East Stroudsburg, Pa.

mers separated in the U.S. in 1960. The only significant use for *m*-xylene today is to make isophthalic acid. Standard Oil of Calif. has a plant rated at 50 million lb./yr. and Amoco can make 30 million lb. in its mixed-xylene oxidation process.

The new Japanese process, commercialized by Matsushita Denko, reacts *m*-xylene (or mixed xylenes) and formaldehyde with an acid catalyst. Resin properties vary with choice of sulfuric, acetic, hydrochloric or phosphoric acid catalyst. When mixed xylenes are used, formaldehyde reacts preferentially with *m*-xylene, leaving the ortho and para isomers.

Only one U.S. company is known to make a related product: Kenrich Petrochemicals Co., Long Island City, N. Y., has non-exclusive license to Socony-Mobil patents for production of resins from formaldehyde and high-boiling aromatics.

Production of cis-polybutadiene in Japan will get under way as a result of a licensing agreement signed by Phillips Petroleum, and Bridgestone Tire Co., Tokyo. Latter firm will build a 10,000-ton/yr. plant using Phillips' process know-how.

Price-cuts alter outlook for oxo alcohols in detergent manufacture

A recent round of price-cutting in oxo alcohols touched off by Enjay Chemical indicates that producers are beginning to feel the squeeze caused by the big capacity buildup (*Chementator*, May 15, p. 54).

The cuts were: hexyl alcohol, from 19¢/lb. to 17¢/lb.; isooctyl and decyl alcohols, from 21¢/lb. to 18¢/lb. (Also believed to be a factor in Enjay's move was a desire to combat imports from England's Imperial Chemical Industries.)

One effect of these price moves may be to make oxo alcohols more attractive for synthetic detergents. Big advantage of oxo-derived detergents is that they can be biologically degraded in municipal sewage plants.

Conventional alkyl-aryl sulfonates cannot be attacked biologically and are present in fairly large concentrations in many rivers that feed municipal water systems. Some observers expect that there will be a legislative crackdown in various areas within two years, requiring that only biologically "soft" detergents be sold.

Esterification of oxo alcohols with sulfuric acid yields straight-chain detergents that meet these requirements. Proctor & Gamble, for example, is now producing small quantities of these materials and some observers believe that volume production of oxo detergents is not too far off.

Biggest outlet for oxo alcohols right now is in plasticizers (estimated 125 million lb./yr. consumption). With 600 million lb./yr. capacity in the offing, a big new outlet in detergents would be a boon to the oxo producers.

Change in liquid oxygen production: elimination of high-pressure cycle

The country's latest facility for making liquid oxygen represents a new wrinkle in air plant design for the builder, Linde Co., Div. of Union Carbide. The 140-ton/day unit at Huntsville, Ala., employs a low-pressure (150 psi.) liquefaction cycle, compared with the high-pressure (2,000 psi.) cycles used in older plants producing oxygen as liquid.

Low-pressure (75-90 psi.) cycles are usually employed in plants producing gaseous oxygen, such as those feeding steel mills. But in order to obtain oxygen as a liquid, plant designers in the past have used a reciprocating compressor to raise the incoming air to high pressures, thus supplying the energy necessary to bring about a liquid product. (Air Products, Inc., uses a dual-pressure cycle. See *Chem. Eng.*, June 16, 1958, p. 66.)

The Huntsville plant employs what is essentially a gas-plant liquefaction system, with a final refrigeration package substituted for the high-pressure reciprocating compressor. Main advantage gained from this is reduction in maintenance problems, with subsequent lengthening of operating cycles.

Incoming air compresses to 95 psi. in a multistage centrifugal compressor. Air passes to a conventional air-separation package that produces a gaseous oxygen product. Oxygen then flows to a refrigeration unit where it condenses against recirculating nitrogen refrigerant.

What prompted the changeover? Linde says it was basically a reduction in condenser area in the refrigeration system that tipped the

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economic scales in its favor. A similar cycle is also used in the liquid oxygen plant that the firm recently put on stream at Neosho, Mo.

Vapor-phase process deposits impervious coatings of tungsten

Allied Chemical Corp. has jumped into commercial production of a new material—tungsten hexafluoride—hoping to cash in on the growing interest in high-temperature materials.

Tungsten hexafluoride is the starting material for a new vapor-phase deposition technique that allows tungsten to be applied to complex shapes at relatively low temperatures. Originally developed by the National Bureau of Standards and the Bureau of Mines, the process shows great promise for space-age tasks such as coating rocket nozzles. Possible industrial applications include long-life metal-working dies and corrosion-resistant tubing.

By using temperatures of only 900-1,200 F., process forms dense coatings with melting points over 6,000 F. Deposits are more than 99.99% pure and free of all pores, which is not true of tungsten laid down by compacting or flame spraying. Coatings can be applied at rates up to 1 mil/min. on both metals and ceramics.

Briefly, process consists of these steps: object to be coated is placed in a ceramic cylinder and hydrogen is introduced. Temperature is raised to 900 F., followed by injection of tungsten hexafluoride and excess hydrogen into the cylinder. As this mixture contacts the heated object, tungsten plates out on the surface. Hydrogen fluoride, the reaction byproduct, flows out with the excess hydrogen and is absorbed.

Nine smog burners pass preliminary tests, face grueling road trials

Nine smog-control devices have survived preliminary screening, out of an original list of sixteen submitted for approval to California's Motor Vehicle Pollution Control Board (*Chementator*, May 1, p. 32).

Those remaining will now undergo a second test, designed to measure actual performance in removing hydrocarbons and carbon monoxide from exhaust gases.

After these two hurdles, the exhaust purifiers that qualify will get a rigorous road test of about 20,000 miles, and simultaneously will be rated for odors, noise and safety.

Latest device to seek approval was submitted by Davison Chemical Div. of W. R. Grace & Co. Davison enters the race with a catalytic system said to operate successfully on gasolines containing lead and other conventional additives. The reactor-muffler, which will use a special Grace catalyst, was fabricated by the Norris-Thermador Corp., Los Angeles.

The Pollution Control Board also had a few applications from additive manufacturers, whose products attack the problem of unburned hydrocarbons by enhancing combustion. All were rejected, presumably because they could not meet the standards that require an 80% reduction in hydrocarbon emission, 60% reduction in CO.

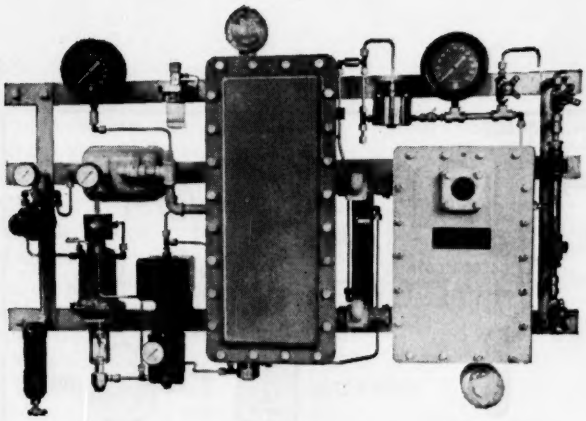
One of these fuel additives, marketed by Fuels Research Corp., Denver, has demonstrated its ability to reduce these emissions by about 25% and has shaved 50% off hydrocarbon output in some tests. While falling below the rigid California standards, such materials may be more attractive than exhaust burners in areas where the emission problem is less critical. Typical cost: about 0.7¢/gal. of gasoline.

Process for "wetting" graphite with metal is being used by Dixon Sintaloy, Inc., Stamford, Conn., to make combinations of metals such as iron, nickel or copper with 10-90% graphite. New materials are expected to find use in self-lubricated bearings, resistance elements and nuclear devices.

Research and development briefs

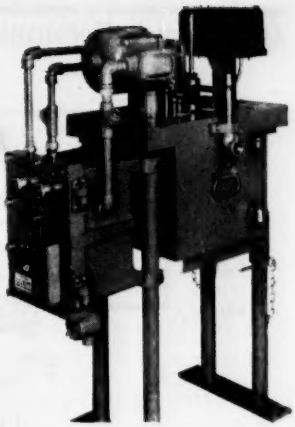
Foam fractionation, developed for treating radioactive wastes (*Chem. Eng.*, Apr. 3, p. 100), is now being investigated for sewage treatment. The Public Health Service has awarded a contract to Radiation Applications, Long Island City, N. Y., to develop a process to remove contaminants—especially synthetic detergents—remaining in biologically treated sewage. Firm expects that air bubbles rising through the water will concentrate surface-active agents in a foam froth that can then be discarded.

For More Industry & Economics News . . . p. 92



VAPOR PRESSURE ANALYZER (left), pay out: one to three months. Continuously samples and records vapor pressure of gasoline or liquefied gases in a flowing stream.

CONTINUOUS VISCOMETER (right), decreases greatly the cost of plant operation by reducing laboratory analyses of viscosity; aids operators in fast, efficient, quality control of refinery operations. Explosion-proof design. Reliable. Rapid pay out.



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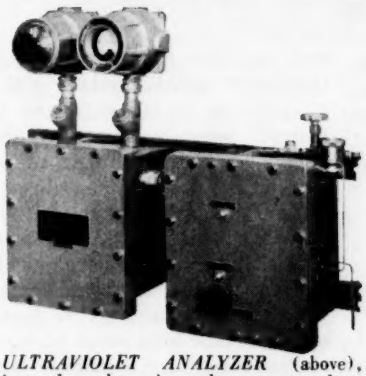
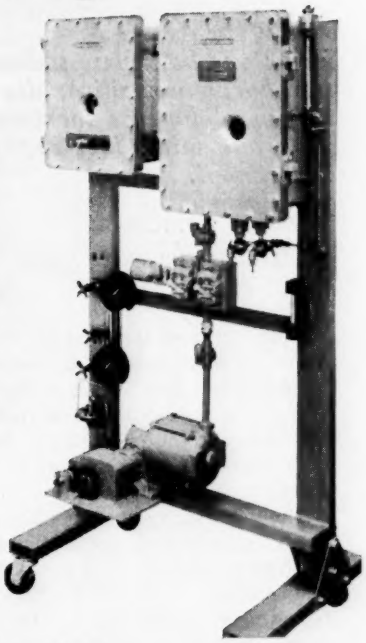
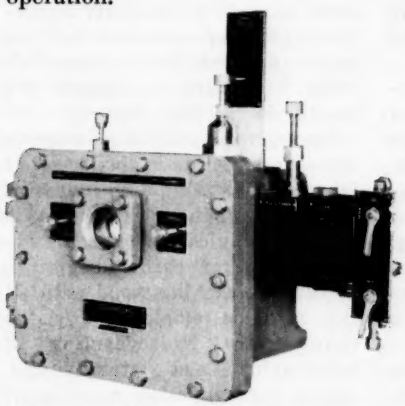


ULTRAVIOLET ANALYZER (above), instantly and continuously measures ultraviolet absorbing components in process plant streams, such as aromatics, diolefins, ketones and aldehydes. Determinations: from few parts to high percentages.

BOILING POINT ANALYZERS: Pictured to the right is END POINT model. Analyzers are of two types. (1) Initial and 10%, and (2) below 90% to end point. Both models are continuous; they lower costs, give better yields and uniform products because of immediate tower control. Pay out: 30 to 60 days.



(All products illustrated are of Shell Development Company design)



COLOR ANALYZER (above), gives electrical output signal to permit the recording of color of petroleum products in color range from pale yellow to deep red. Uses ASTM glass color-standards for calibration purposes.

Two of many other Hallikainen products (not shown): (1) *ALKYLATION ACID ANALYZER* for determining the strength of acid in sulfuric acid alkylation plants; (2) *MICROMALYZER*, a low cost, compact precision chromatographic laboratory instrument for detection of hydrocarbons.

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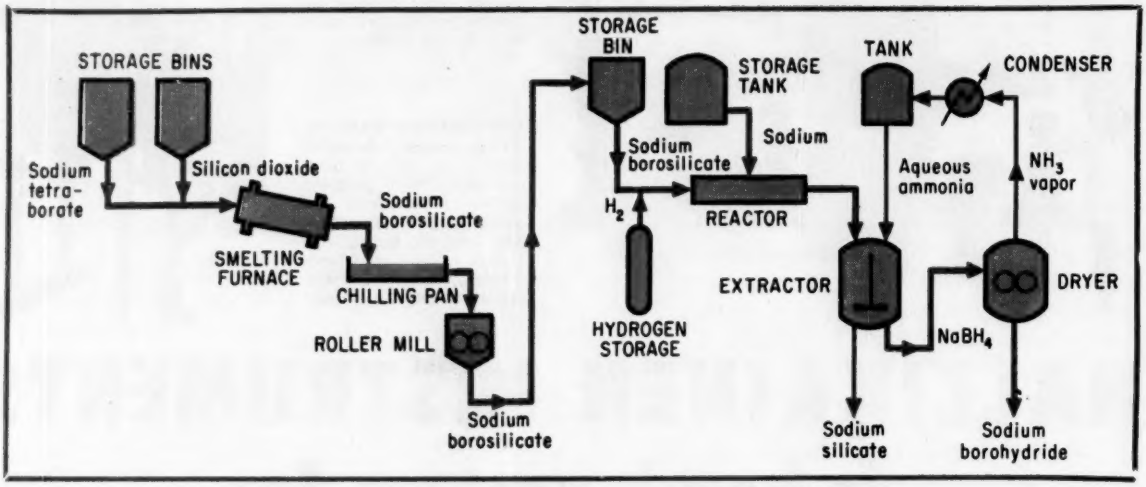


SOLIDS-GAS REACTION SLASHES PRODUCTION COST, BRIGHTENS SODIUM BOROHYDRIDE FUTURE

Reaction between sodium tetraborate and silicon dioxide in solid phase increases yield and minimizes capital investment.

T. P. FORBATH

McGraw-Hill World News, Bonn, Germany

West Germany now has its first major domestic source of sodium borohydride. And it got it via a brand new process that reportedly can turn out the chemical at less than one-fourth the current U. S. selling price.

The process involves reaction of borax, quartz and sodium under hydrogen pressure of 3 atm. at a temperature of 450-500 C. This is followed by extraction of the sodium borohydride from the solidified mixture of $NaBH_4$ and Na_2SiO_3 with aqueous ammonia.

Author of this double-edged challenge to America's dominant position is Farbenfabriken Bayer AG. The company is currently putting finishing touches on an 80,000-lb./yr. facility at its big Leverkusen works near Cologne. And it's readying a major marketing program aimed at overseas as well as home markets, in which top-purity white crystals will be offered for $8.50 and less per pound, depending on quantity. This compares with the present U. S. l.c.l. price of $33-40/lb.

▶ **Big Potential Market**—Bayer is convinced that this development will change sodium borohydride's present status as a moderately used specialty chemical to that of an important bulk commodity.

Previously, the company maintains, engineers and chemists have been forced to steer clear of the material because of its high price, despite its intriguing and versatile properties. Now, however, new applications in paper and pulp, pharmaceuticals, dyes and plastics can be economically commercialized. Furthermore, use of the material is sure to expand.

Bayer, of course, is well aware of the potential of sodium borohydride as an intermediate in the production of high-energy boron compounds that once looked so promising for use as rocket propellants. But, for the moment at least, it isn't figuring this application as one of the major outlets for the new product.

In the first place, West Germany has no rocket fuel industry to speak of, let alone an exotic-fuel industry. Then, too, interest in boron-type propellants has waned considerably. Still, Bayer isn't counting out the possibility that the sharply reduced price of its $NaBH_4$ could reawaken activity.

Right now, though, Bayer feels that nonmilitary applications are great enough to keep its Leverkusen plant operating at full capacity. In fact, the company already has plans to expand the facility in the near future.

Among the applications seen is use as a selective reducing agent for various organic materials. For example, $NaBH_4$ can be used to stabilize cellulose through the hydrogenation of carbonyl groups, serves in bleaching wood pulp. It can also be employed for the stereospecific hydrogenation of ketosteroids and streptomycin, speeds the reduction reaction of such materials as vat dyes and aromatic nitrogen compounds.

In addition, sodium borohydride can be used for generation of high-purity hydrogen via reaction with water over a catalyst. As a result, it can serve in the foaming of rubber and various plastics. Bayer also visualizes its use for the manufacture of boron hy-

drides, amino and alkyl boranes, esters of borinic acid and hydrazine boranes.

▶ **Piloted Five Years**—Bayer's new process is the direct descendant of some five years of pilot-planting solid-phase routes. In this operation, the company set out on an entirely different tack than did American producers.

U. S. firms such as Callery Chemical Co. and Metal Hydrides, Inc. built their flowsheets on the basic liquid-phase reaction involving sodium hydride and trimethylester boric acid in a boiling solvent at about 260 C. (While refraining from commenting on other processes, Bayer engineers feel that liquid-phase reactions don't give high enough yields.)

Originally, Bayer sought a commercial process employing calcium hydride, sodium metaborate and sodium under 60 atm. hydrogen pressure at 450-600 C. However, the feed materials required expensive preparation. To insure a high degree of reactivity, they had to be milled to a fine powder and intimately mixed. To prevent losses through dusting, they had to be briquetted. Then, too, the high pressure meant elaborate and expensive equipment.

Bayer then worked up a process based on the reaction of sodium and borax at 450-500 C. under only 3 atm. H_2 pressure. But the yields were far from satisfactory. Competing side reactions took place between the sodium tetraborate and such intermediate compounds as sodium oxide to produce meta- and orthoborates.

▶ **Low-Pressure Route**—Finally, the company merged the attractions of the two routes, eliminated the disadvantages. Bayer claims to get better than 90% yields, and to have reduced capital investment by eliminating high-pressure vessels, milling, mixing and briquetting equipment.

At the Leverkusen plant, anhydrous sodium tetraborate and silica are fed to a rotating smelting furnace, where sodium borosilicate is produced. This material goes to open chilling pans where it solidifies, then passes through roller mills into a storage hopper.

The borosilicate, hydrogen at 3 atm., and sodium are fed to a reaction vessel.

In the reactor, the temperatures run 450-500 C., which keeps the sodium molten. The reaction essentially is:

$$Na_2B_4O_7 + 16Na + 8H_2 + 7SiO_2 \rightarrow 4NaBH_4 + 7Na_2SiO_3$$

The mix then discharges to an agitator-equipped extractor where aqueous ammonia dissolves the sodium borohydride. The solution is fed to a dryer that drives off the ammonia, which is condensed for re-use. The sodium borohydride crystals are further dried, and discharged ready for packaging.

WHAT CURE FOR THE ATOM-POWER INDUSTRY'S GROWING PAINS?

In the face of mounting disillusionment with atomic power, industry men are reexamining the economics of atomic fuels.

The Atomic Energy Commission recently announced that it was terminating an agreement with two groups of utility companies to build an experimental 50,000-kw. reactor in Polk County, Fla. Thus far, only one project—Yankee Atomic Electric Co.'s 110,000-kw. plant at Rowe, Mass.—has been completed under the program for joint development of nuclear power by the government and private industry, inaugurated in 1954.

Commission officials have blamed the slowdown in the program on the reluctance of most utilities to accept the financial burden of building atomic plants in view of the present technical and economic uncertainties about nuclear power.

Speaking before the American Power Conference recently held in Chicago, T. G. Le Clair of the General Atomic Div. of General Dynamics defined some of these uncertainties in terms of areas in which cost improvements can be made.

"Spectacular gains can be achieved in the area of increased power density in the reactor core. The power density in the core of the Peach Bottom reactor, this country's first high-temperature gas-cooled power reactor, is about 20 times the power density at England's Calder Hall, the world's first gas-cooled power reactor.

"The steam turbine for a reactor power plant is of nearly conventional design. However, most present-day reactors produce steam at pressures and temperatures that were standard for turbines many years ago. Therefore, the turbine-generator efficiency can be brought up substantially as soon as the reactor is able to produce the necessary higher temperatures."

Turning to fuel cost, Le Clair cited the expensive separation processes needed today to recover the small percent of burnable fuel present in natural uranium.

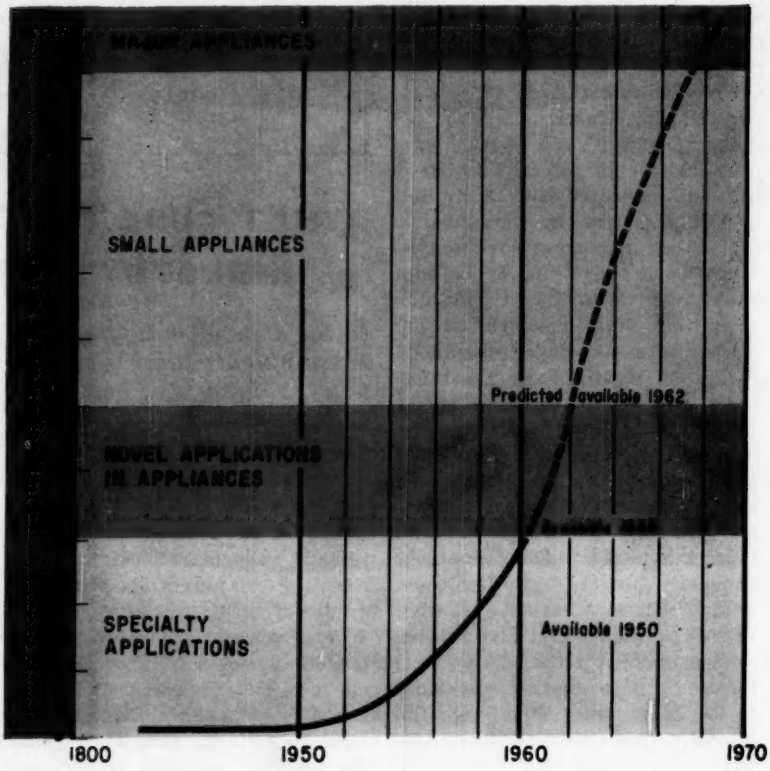
"The second item that adds to the fuel cost is cladding. Fabrication methods, at least up to the present, have given rise to the remark that the fuel elements in a nuclear power plant look like a Swiss watch, and cost more per pound.

"A third problem in the cost of nuclear fuel is the matter of burnup. Only a certain portion of the fuel can be burned before the fission products created will absorb the neutrons and shut down the reaction. You might say that the ashes put out the fire. With today's technology, we are a long way from using the fuel efficiently."

He also pointed out that the present prices of uranium were set when it did not appear to be plentiful, and when methods of concentrating and refining were not fully developed. The industry is so new that he expects lower prices before long.

ELECTRONICS MAKERS CALL FOR MORE CHEMICALS

Chemical makers are being tapped for new thermoelectric materials, as well as high-purity silicon for semiconductor devices. The required grades often sell for more than ten times price of commercial grades.



Thermoelectrics is the latest branch of electronics to promise fertile markets for chemicals. An estimated $40 million worth of thermoelectric materials is expected to go into devices for industrial, consumer and military use by 1965.

Present indications are that the following elements will play major parts in this growth: tellurium, arsenic, bismuth, gallium, indium, antimony, lead. The lesser known of these are originally produced as refining byproducts of major metals, i.e., copper, lead, aluminum, zinc.

Chemical operations enter the picture with the steep upgrading that must be performed on these materials. To qualify for thermoelectric use, materials must be ultrapure and put into exactingly controlled combinations, often with each other.

▶**Fleet Forerunner**—As an immediate forerunner of the thermoelectric materials, high-purity silicon has been setting a fancy pace. The electronics industry has already furnished markets in semiconductor devices, responsible for high-purity silicon's doubling in production each year from 1956 through 1959. The Bureau of Mines estimates production was 80,000 lb. in 1959. Total value, at an average price of $300/lb., amounted to $24 million.

The electronics industry has also conjured up a $5-million market for etching mixtures (hydrofluoric, nitric and acetic acids) and for cleaning solvents, of a purity consistent with the manufacture of semiconductor devices. Now that device manufacturers have begun to automate, this market promises to grow even faster since automation requires increased use of reagents.

▶**Sunny Vistas**—The $40-million figure for thermoelectric materials is based on projections* for $400-million sales of devices in 1965. The 1961 estimates:* combined industrial and consumer retail sales of thermoelectric cooling and heating products are expected to hit $1 million; military expenditures on thermoelectric cooling, several million. On thermoelectric power generation, there are over 800 companies doing research and development. During 1960, the total sum spent for R&D as well as retail, industrial and military sales was over $10 million.

With the kind of volume expected by 1965, materials costs should represent about 10% of the total. Today, however, their slice is more like 30%.

▶**Price for Upgrading**—Such prime producers as American Smelting & Refining, Consolidated Mining, Canadian Copper Refiners Div. of Noranda Mines, Indium Corp. of America and Kawecki Chemical have started marketing high-purity as well as commercial grades of the thermoelectric materials. Number of high-purity elements offered by Asarco went from 2 to 15 in the past six years, giving it the top volume and range in the field. Commercial-grade ma-

*"The Outlook for Thermoelectricity," R. A. Bernoff, Materials Electronic Products Corp., presented at the University of Pittsburgh Conference on Business Prospects, Nov., 1960.

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In addition to its solvent action, furfuryl alcohol contributes desirable properties to epoxy formulations in its own right. For example, when 100 parts of an epoxy is catalyzed with a solution of 3 parts BF_3 MEA in 10 parts of furfuryl alcohol:

1. the viscosity of the resin at 27°C. is reduced from 10,600 to 600 centipoises;
2. on heating this formulation above 85°C. the furfuryl alcohol reacts to become an integral part of the dark amber resin solids;
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For more complete technical data and test reports, write for Bulletin 138.

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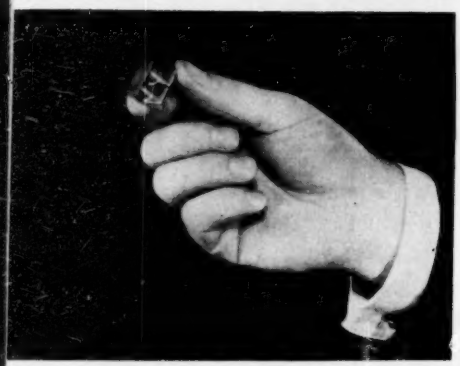

Thermoelectric materials—like those of Melcor shown here—are produced as modular units (top) consisting of several individual couples (above).

terials average 99.50-99.98% pure. The new grades run to 99.999+% pure. Prices of the commercial grades bear very little relationship to prices of the high-purity materials, but as a broad guide, they are about one-tenth.

However, there is another group of producers growing up, neither prime producers nor device makers, that buys from the former and sells thermoelectric material in directly usable alloyed form to the latter. This group includes Minnesota Mining & Mfg., Merck, Materials Electronic Products (Melcor), Ohio Semiconductor, Westinghouse (whose device making division is separate from its materials making division).

Their products often take the form of modular units wherein precisely constituted wafers of thermoelectric alloys are sandwiched between slices of rigid plastic foam. To get an idea of the cost of this upgrading stage: high-purity tellurium is sold by such companies as Asarco at about $30/lb. (compared with $4/lb. for commercial grade). Tellurides contained in Melcor units, when ordered in production quantities, costs $45/lb.

▶**Who Does What**—Generally, members of this group consider themselves raw-material producers rather than component fabricators, but there is room for controversy. Such controversy recently sharpened in high-purity silicon with the emergence of so-called "epitaxial" silicon. Epitaxial silicon is the result of a new-growth extension of the original crystal by means of which the crystal maker can add exact amounts of the impurities needed to give the electronic device the desired electrical properties.

Many device makers consider it part of their job to add the impurities, which impart special electrical properties. But Merck has already started offering the epitaxial material commercially, and Du Pont, Monsanto and Dow Corning are also expected to bet on them as chemicals, not components.

In fact, at least half of the ten-odd major producers of high-purity silicon have their roots firmly planted in the chemical rather than the electronics industry. All of them are seriously eyeing thermoelectric materials as a logical extension of the competence gained in creation of ultrahigh purities, though the most serious commercial performer has been Merck.

Adding further confusion to a decidedly unsettled situation, some of the chemically oriented entrants buy commercial rather than high-purity grades of materials from the prime producer because they see greater economies in doing their own purification. On the other hand, some of the prime producers alloy their elements to thermoelectric combinations.

▶**Magic Junction**—Thermoelectricity is based on discoveries that electric power is generated by heating the junction of two dissimilar metals, and that passage of current between that junction causes absorption or evolution of heat. Recent major advances in the development of semiconductors have made it possible to markedly increase the efficiency of thermoelectric effects.

To be an efficient power-generating material, a sizable voltage should be produced by a small temperature difference. This is called Seebeck potential. Also important: electrical conductivity, since electrons must be used to pump heat; thermal conductivity, which must be low because temperature difference must be maintained between the ends of a device. These three factors determine the figure of merit, which is a measure of the efficiency of the thermoelectric material.

▶**Which Materials**—A wide variety of materials have been investigated for thermoelectric power applications, including: tellurides, selenides, oxides, nitrides, carbides, arsenides and silicides of metals including the transition elements.

Of all, bismuth telluride and lead telluride systems have given the highest efficiencies. Due to an emphasis on high temperature of operation in association with reactor heat sources (about 700 C.), lead telluride is more widely used at present. Bismuth telluride alloys, give equal or greater efficiencies, although operating temperatures are limited to 300-400 C. To date, bismuth telluride and its alloys are the best materials that have been developed for cooling applications. At present efficiencies, they are suitable for small-system consumer applications such as dehumidifiers, water coolers, portable refrigerators for cars, boats and camping. Current industrial applications are outdoor fluorescent fixture cooling, electronic component cooling, laboratory equipment cooling.

Bismuth and tellurium are each expected to have 200,000-300,000 lb./yr. thermoelectric markets by 1965. According to the Bureau of Mines, consumption of bismuth in experimental uses increased from 87,018 lb. in 1958 to 161,040 in 1959; the increase is attributed largely to work on nuclear and thermoelectric projects.

▶**Tellurium Problem** — There's

NOW ULTRASONIC LIQUID LEVEL CONTROL

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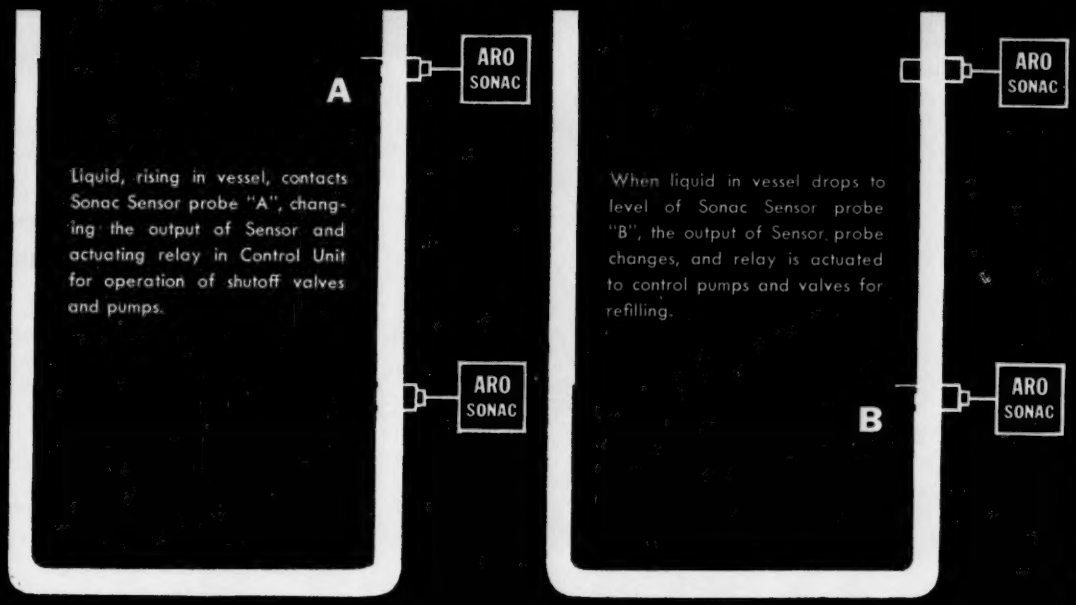
SINGLE SENSOR


A
ARO SONAC
Liquid, rising in vessel, contacts Sonac Sensor probe "A", changing the output of Sensor and actuating relay in Control Unit for operation of shutoff valves and pumps.
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When liquid in vessel drops to level of Sonac Sensor probe "B", the output of Sensor probe changes, and relay is actuated to control pumps and valves for refilling.
ARO SONAC
B
ARO SONAC

Provides uncanny accuracy and dependability with installation ease and economy

Now, performance no other liquid level control system can offer is a practical reality with new Sonac Ultrasonic Single Sensor System. Sonac is unaffected by foam, liquid viscosity, specific gravity or vibration. The sensor is inherently explosion-proof, and models are available to cover the range from −425°F. to 450°F. Amplifier is fully transistorized, and sensing unit is hermetically sealed in stainless steel, thus maintenance is seldom needed. Sensitivity is adjustable to provide repeatable *accuracy of liquid level control to .005"*. Normally, two Sonac Single Sensor systems will be required for high-low control. Installation is easy, and a variety of accessories is offered.

See your ARO distributor for a demonstration, or write ARO for complete information.

(Sonac is the registered trademark of the Delavan Mfg. Company.)

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SONAC Two-Sensor System
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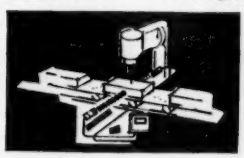
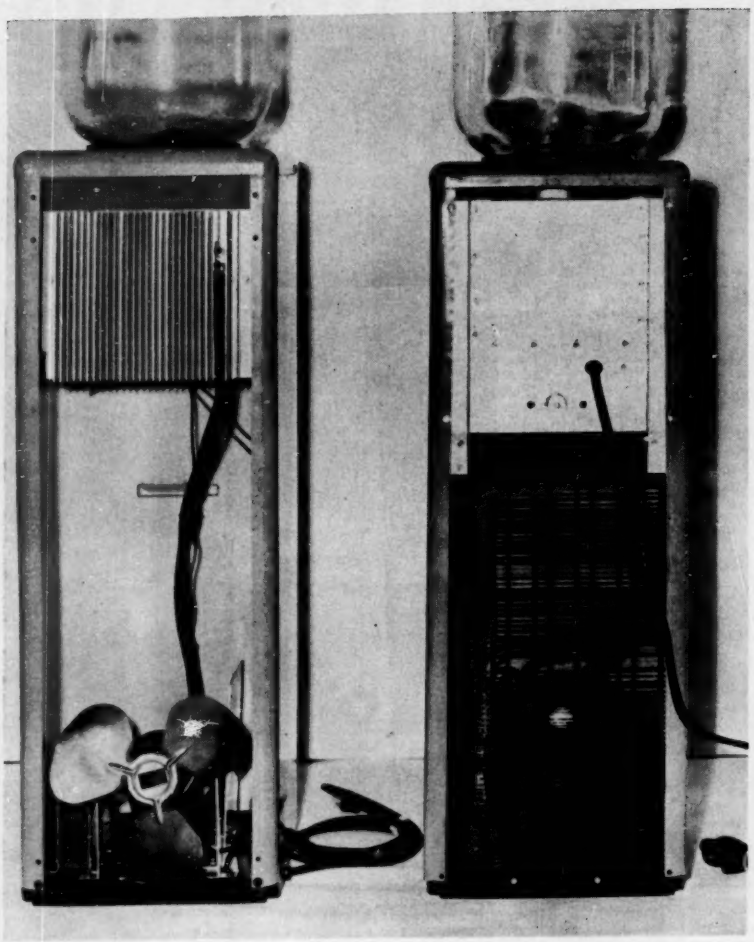
Operates under conditions that foil other sensing devices. Requires no light, has no filament to burn out, will operate in contaminated atmospheres, darkness . . . and can even be piped through flexible hose or tubing. Get complete information from your Aro distributor, or write Aro.





Thermoelectric components of Westinghouse water cooler (left) take 25% less space than those in standard unit shown at the right.

talk already of future shortages of tellurium. It is actually a rare element and has never been found in large deposits or broadly distributed in even small amounts with other minerals. Most of today's tellurium comes from certain deposits of copper and lead. In these ores, tellurium content is extremely small.

All North American producers could turn out about 750,000 lb./yr. To reach that figure, copper demand would have to be at a high rate—no producer will mine unneeded copper just to get tellurium. Backstopping production potential is an estimated 1 million lb. of tellurium that can be refined from muds and residues that have been accumulated by refineries. Most of the residues are owned by Asarco, the nation's largest producer.

One government expert foresees a day, before the end of this decade, when military uses alone will consume this entire reserve.

Producers have been encouraging users of commercial grades of tellurium (for vulcanizing rubber, free machining copper, catalysis) to seek alternative materials so that the bulk of existing supplies would be available in the more expensive high-purity form. Several hikes in the past two years have doubled the price of commercial grade to \$4-\$5/lb.

On the other hand, prices of telluride in ready-to-use thermoelectric alloys have come down to a low of \$45/lb. from about \$500/lb. in 1959 (though sample quantities are still high).

Reduction is due to better production methods. Also, work is underway to reduce amounts of tellurium required; for example, a use that takes a pound of tellurium today might require only 3 oz. five years hence.

There are also, of course, strenuous efforts to uncover superior alternate materials. Right now, for example, lead telluride in high-temperature thermoelectric uses is said to be threatened by a silver-antimony-tellurium system developed by Bell Telephone Laboratories.—FA

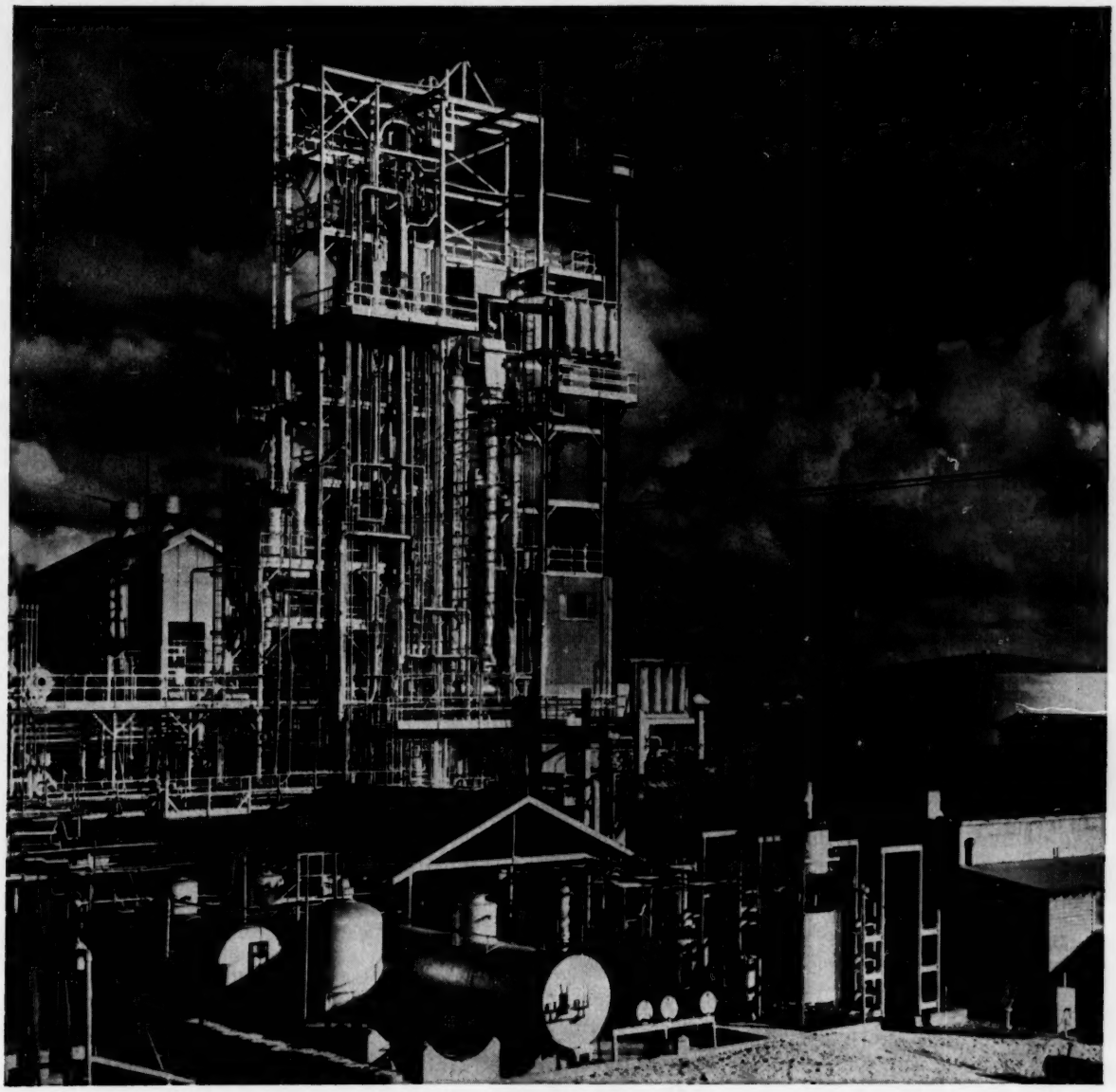
More Research Information To Be Made Available

The Dept. of Commerce's Office of Technical Services recently announced availability to industry of almost twice the current number of U. S. military research and development reports, opening up a vast new source of technical information.

J. C. Green, director of OTS, described his four-part program to the American Institute of Chemists' annual meeting in Washington:

- From now on, OTS will make available to the public (by microfilm, Xerox reproduction, or order of surplus prints) all unclassified military research reports published by the Armed Services Technical Information Agency.
- Effective in July, OTS's monthly journal—*U.S. Govt. Research Reports*—will become a semimonthly (\$15/yr.), each issue abstracting some 2,500 federal agency (civilian and military) reports.
- A technical literature-searching service will be inaugurated by the Library of Congress. Charge to all comers: \$8/hr.
- OTS will annually publish abstracts of all government-owned patents released during the year for license to private industry.

As Green pointed out, "It would be difficult to find a better bargain basement for information than OTS."



BACK IN FULL PRODUCTION...

thanks to Enjay Technical Service

Recently, a major producer of alkyl phenol was forced to halt production due to an unknown "catalyst poison." Enjay, the supplier of one of the raw materials, was asked to help assist this company's technical people in finding a quick solution to the problem.

Using a combination of modern laboratory instruments and advanced organic chemical analyses, the poison was identified as phenol ether, traceable to a leak in the heat exchange unit. The plant was quickly able to repair the heat exchanger and resume full production.

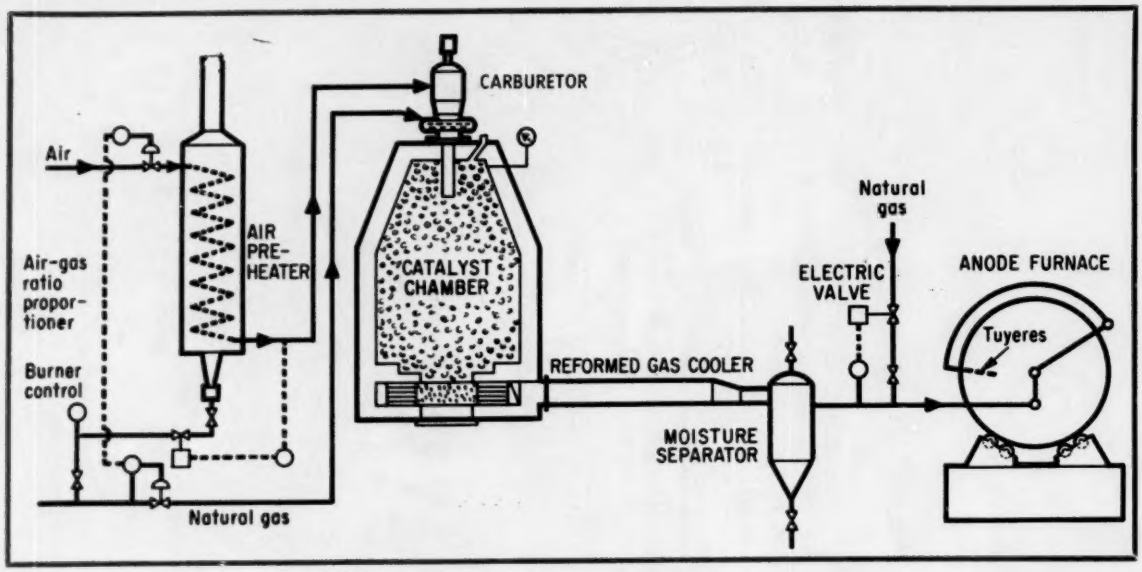
Enjay Technical Service is available to help customers solve production, application and development problems on a wide range of products. If we can be of service to you, write to Enjay, 15 West 51st Street, New York 19, New York.

EXCITING NEW PRODUCTS THROUGH PETRO-CHEMISTRY

ENJAY CHEMICAL COMPANY

A DIVISION OF HUMBLE OIL & REFINING COMPANY

ENJAY
CHEMICALS



Heart of new process is the reformer that catalytically converts natural gas to hydrogen and carbon monoxide.

GAS REDUCTION—NEW ROUTE TO COPPER REFINING

Following extensive tests, Phelps Dodge Corp. finds reformed natural gas has many advantages over the conventional poling method.

At Phelps Dodge Corp.'s, Douglas, Ariz., copper smelter, the wood pole that formerly jutted from the end of the anode converter is a thing of the past.*

For more than two years, the company has been reducing oxygen-containing copper with reformed natural gas (*Chem. Eng.*, Oct. 17, 1960, p. 94). And following the processing of more than 100,000 tons of copper by this method in two 13X20-ft. rotating gas-fired furnaces, the company reports it has:

- Eliminated a hazardous and untidy operation.
- Simplified the reduction procedure.
- Substantially reduced refining costs.

The natural gas available at Douglas is free from H_2S. It consists of CH_4, CO_2, N_2 and small amounts of higher homologues of CH_4 (see accompanying table). For practical purposes, it can be considered simply as methane. The basic reformer reaction then becomes:

$$CH_4 + \overbrace{0.5O_2 + 1.88N_2}^{\text{air}} \rightarrow CO + 2H_2 + 1.88N_2$$

Air:CH_4 ratio = 2.38

To compensate for sensible heat losses, however, it was found practical to use an air to gas ratio of 2.85-3.00.

▶**Reformer Flowsheet**—Main units in the reformer are: (1) a specially designed carburetor, (2) catalyst chamber, (3) air to gas ratio proportioner, and (4) emergency natural gas injector at the two anode furnaces.

Preheated air is injected tangentially near top of carburetor, and room-temperature natural gas through holes in the manifold that encircles the base of the carburetor.

The thoroughly mixed air and gas is ejected from the carburetor outlet port and impinges, without backfiring, on the catalyst mass. Catalyst is a commercial product consisting of irregularly shaped lumps of Alundum (⅜-1½ in. dia.) impregnated with 6.55% nickel.

To start up the reformer, a small flow of preheated air is passed through the catalyst mass until it reaches 1,000 F. The air is then augmented with natural gas in roughly a 3 to 1 ratio to initiate the catalytic reaction. When the reforming gas attains desired temperature, air to gas ratio is decreased slightly.

Once in operation, the reformer may be stopped and restarted without warming up, having been

Analysis of natural gas used in reformer at Douglas

Constituent	Volume Percent
CO_2	0.16
N_2	2.79
O_2	0.01
CH_4	86.01
C_2H_6	8.60
C_3H_8	1.95
C_4H_{10}	0.29
C_5H_{12}	0.19
Total	100.00

* This article is based on a paper, "Gaseous Reduction of Oxygen Containing Copper," by Leonard Klein, Research Chemist, Phelps Dodge Corp., presented at the Annual Meeting of AIME, St. Louis.

A NEW ADDITION TO THE SONAC *LINE*

POSITIVE ULTRASONIC LEVEL CONTROL

The components of Sonac (sensor actual Size)

Now, two new ultrasonic sensors, especially for level control have been added to the Delavan line of SONAC sensing and switching devices.

The single sensor system is recommended for liquid level control and the double sensor system for dry level control.

Control is maintained by installing the SONAC sensor through the wall of the vat, bin or hopper. When the oscillation on the face of the sensor is dampened or impeded by the material being sensed, the signal to the control unit changes, activating a relay.

FIG. 1—LIQUID LEVEL (One Sensor)

FIG. 2—DRY LEVEL (Two Sensors)

For level control, SONAC is accurate to .005" and has a response time of 25 milliseconds. Performance of the sensor does not deteriorate with age.

The level control uses to which SONAC can be applied are virtually unlimited. It is not affected by the viscosity*, specific gravity, conductivity, or capacitance of the material being sensed. Temperature or pressure changes of the material do not alter its performance. False signals are eliminated because SONAC may be adjusted so as not to sense steam, foam, or vapors.

*Viscosity may affect response time.

Canadian Representative:

KNOWLES & FOSTER (North America) Ltd.

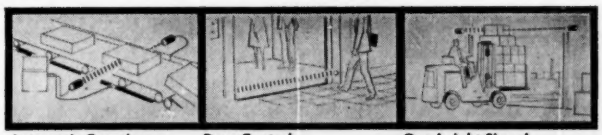
708 Terminal Bldg., Toronto 1, Ontario, Canada

A

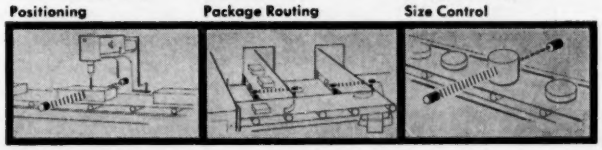
SONAC is extremely rugged. Sensors are type 304 stainless steel. The electronic components in the sensors are hermetically sealed and will withstand pressures to 2000 psi and temperatures from −425° F. to +450° F. They are immune to shock, vibration or mechanical damage.

The control is a compact unit 5" x 5" x 5" and features transistor circuitry. Power consumption is one watt and the unit will operate in temperature ranges from 40° F. to 135° F.

Here's how SONAC can be used for sensing and switching applications other than level control.



Automatic Counting Positioning | **Door Control Package Routing** | **Overheight Signal Size Control**



There are dozens of applications for SONAC *single and double sensor units. Let it go to work for you now, write:*

DELAVAN *Manufacturing Company*

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shut down for 48 hours in winter without difficulty.

Air-gas flow to the carburetor is controlled by a proportioner that interlocks the air and gas flowmeter controls. When reformer is started, gas flow starts, closely followed by air. During operation, the proportioner maintains required air-gas ratio regardless of variations in line pressures. When operation stops, both flows are instantly shut off.

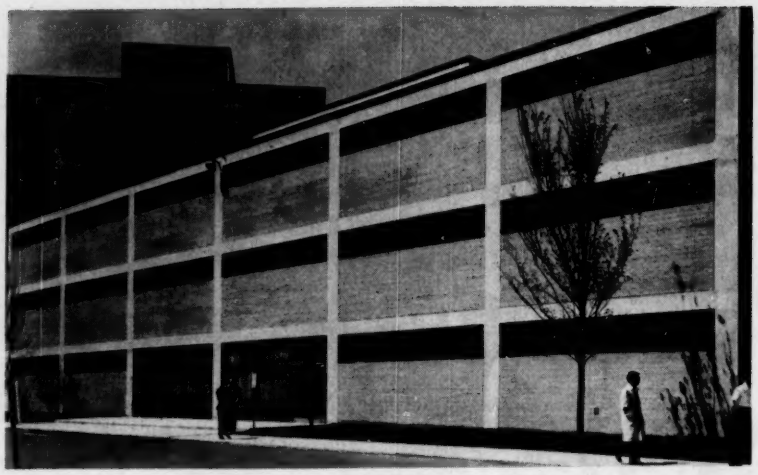
▶ **Reducing the Charge**—Molten copper as transferred from the converter to the anode furnaces contains a variety of impurities that must be oxidized and removed as slag. Following removal of the slag by skimming, oxygen content of the copper may be 0.7-0.8%. Reduction of this undesirably large oxygen content, which was formerly accomplished with oak poles, is now done with the gas.

At Phelps Dodge, the reformed gas feeds to the furnace through two upturned tuyeres. As the furnace rotates, the tuyeres are slowly submerged, permitting the gas to bubble through the charge of copper. Degree of submergence varies according to the judgment of the operator.

Reduction is continued until the O_2 content has been lowered to a predetermined point—normally below 0.2%.

To protect the submerged tuyeres against failure of reformed gas or air flow, an electrically operated valve is installed in the gas line leading to the furnace meter. If volume of reformed gas or air in furnace line should drop below a preset value, this valve opens and allows high-pressure natural gas to enter the line, thus blocking flow of molten copper into the tuyeres. The valve also actuates an electric horn.

The reformer plant is designed to be operated by pushbuttons on the main control panel at the reformer, or from either of the two furnace control panels. No operator is required at the reformer at any time. A system of signal lights on the main control panel enables refiner operator to pinpoint any malfunctioning unit.



New chemistry building at Chicago headquarters of cosponsor Armour Research.

NEW TRENDS IN CHEMISTRY TO BE SUBJECT OF UPCOMING CONFERENCE

Two-day meeting will probe industrial potential of new chemical discoveries.

What's been happening on the frontiers of chemistry? In an effort to supply a concise and meaningful answer to this far-reaching question, Armour Research Foundation and *Chemical Engineering* are sponsoring a technical conference on "New Trends in Chemistry."

To be held in Chicago on October 11 and 12 at the Sheraton Towers Hotel, the conference is designed primarily for engineers who have been out of school for more than five years. Its goal is to translate discoveries of scientists into terms that can be applied by engineers working on the industrial level. Among the topics to be examined at the two-day meeting are plasma chemistry, inorganic polymers, organic semiconductors, nonaqueous chemistry, kinetics, and catalysis.

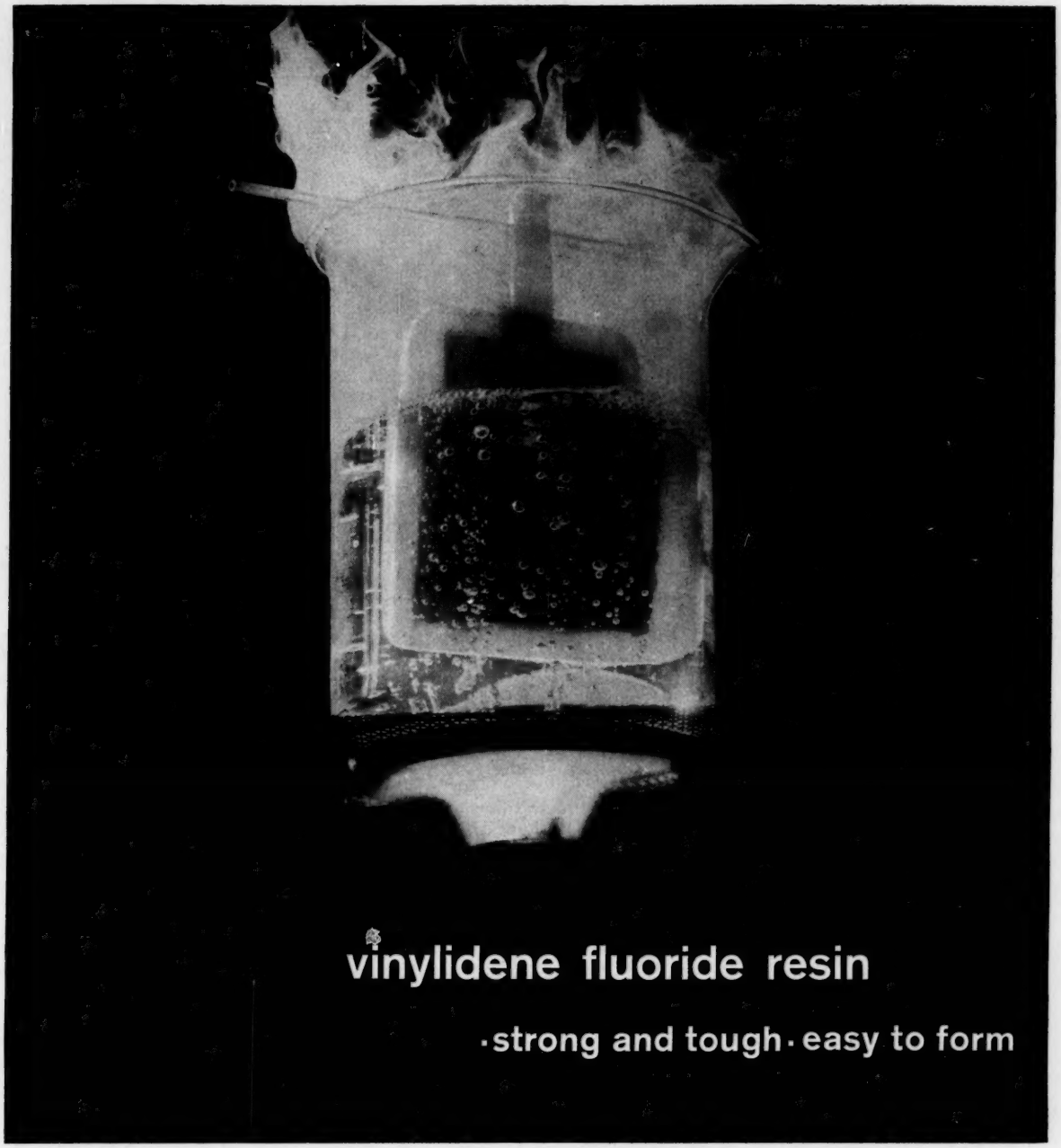
Cosponsor ARF has a big stake in chemical research, having just completed a $3.5-million chemistry building at its headquarters on Chicago's near south side.

Armour has about 1,200 engineers, scientists and other professional personnel on its research staff. Last year, its twenty-fourth in the research business, the nonprofit foundation performed contract research worth $16,190,000. Government projects accounted for 357 of ARF's 785 research programs, while 343 projects were carried on for industry and 85 were conducted by the foundation under its own auspices.

Among the more exotic problems in physical chemistry that ARF had to contend with recently was the elimination of contrails from jet aircraft. These are caused by the condensation of water vapor from the plane's exhaust system on nucleating particles formed by jet fuel combustion.

Working with Cornell Aeronautical Laboratories and Allied Research Associates, Inc., under Air Force sponsorship, ARF researchers discovered another material on which water vapor would condense. They then developed an additive using this material to disperse the water droplets into particles less than 0.00002 in. dia., rendering the vapor invisible.

A large portion of the chemical research now going on at ARF is concerned with space technology.



Encased in protective envelopes of Kynar film, these mild steel test coupons have been immersed continuously for over three weeks in boiling nitric acid. The coupons show no sign of corrosion.

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*Kynar is a trademark of Pennsalt Chemicals Corp.

Sodium-Chlorine System Boosts Limit On Fuel Cell Voltage, Power Output

A new version of the sodium-amalgam fuel cell was unveiled at the recent Power Sources Conference, held in Atlantic City, N. J., under sponsorship of the Army Signal Corps. Developed by J. S. Smatko of Hoffman Electronics, Los Angeles, the cell employs chlorine or bromine as the oxidizing agent. Fuel is sodium, charged as an amalgam to minimize the handling problem. Experimental cell shown at the left delivers 1 w. at 3.3 v. (open-circuit) using the Na-Cl_2 system. (By comparison, a hydrogen-oxygen cell has an open-circuit voltage around 1.0.) Though sodium is too expensive for use in a cell intended for consumer markets, the Na-Cl_2 unit could find military applications; the Navy, for example, is investigating fuel cells for providing silent submarine propulsion.

One program is devoted to the use of fuel cells to provide power in space. Another project just completed showed that the photolysis reaction of photosynthesis is a feasible way to supply astronauts with water.

Sectional-Charge Approach May Boost Solid Fuels

A variation on standard segmented rocket engines (*Chem. Eng.*, May 15, p. 64), called "sectional charge" method, is the latest idea in the race for thrust. Hercules Powder Co. says it could have a multimillion-lb.-thrust booster operable within 24 months using this technique.

Firm proposes using a number of solid-propellant cylinders, each 170-in. dia. and 8-ft. long. Rocket would be constructed at the launching site by stacking six cylinders atop one another, then wrapping the system in epoxy-reinforced fiber glass. Cluster of seven such units would deliver several million pounds thrust. This concept has been proved feasible on smaller rocket engines built by Hercules.

Fluid Catalytic Cracking: Third-Generation Design

The third design in a series of fluid catalytic cracking units developed by M. W. Kellogg Co., outperforms its predecessors by giving a higher yield of liquid products with less coke and gas.

Called Orthoflow C, the latest design retains the basic principle of straight-line flow of catalyst between vessels, which virtually eliminates erosion commonly encountered in systems containing pipe bends. Two commercial units are under construction.

In a grass-roots unit, reduction in coke product can be as much as 2% (by weight) of the feed, or gasoline yield may be increased as much as 2.3% (by volume) of feed. Older units converted to Orthoflow C will have different yield increments depending on whether higher conversion or higher capacity is sought.

Yield improvement stems from three features:

- Fresh-feed transfer-line temperature is optimum for high conversion.
- Catalyst is rapidly separated from transfer-line effluent.
- Recycle oil is cracked at more-severe conditions than those imposed on virgin feed.

In operation, fresh feed and recycle pass upward through separate risers after admission to the system through the hollow stems of regenerated-catalyst plug valves, which control the relative amount of catalyst fed to the risers.

The feed and recycle streams, carrying hot regenerated catalyst upward, discharge at different levels in the reactor section. Recycle oil is sprayed low in the catalyst bed to insure that it receives more-severe treatment than the fresh feed, which is cracked only in the transfer line. Yields may be adjusted by altering length of risers.

Spent catalyst is stripped of vapor with steam, in a zone just below the reactor, then passes downward to the regenerator where its carbon content is reduced to the desired level by contact with air. Hot regenerated catalyst is then admitted via the plug valves to the feed and recycle risers.

Flue gases from the regenerator may not only be expanded to recover significant power, but may be used to generate additional power by burning in a CO boiler. In a new installation, CO combustion may reduce investment for boilers.

When you need fast, easy opening and closing with a leak-proof seal and straight-through flow with minimum pressure drop specify

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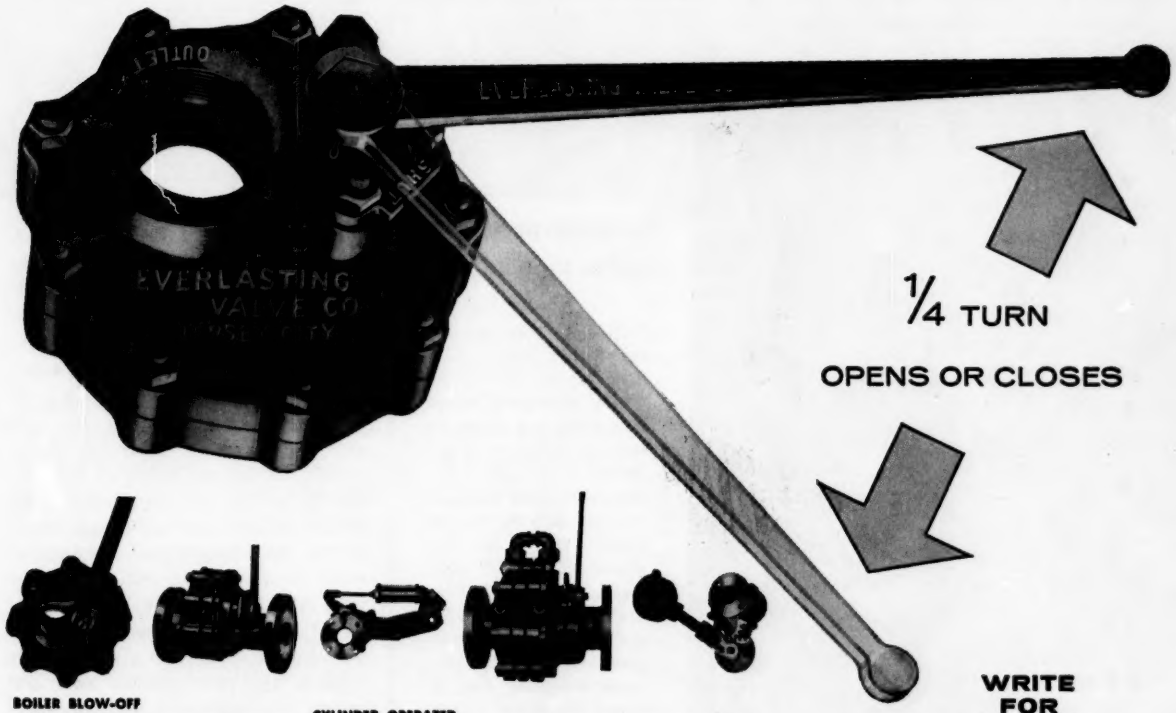

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Can be remotely controlled, electrically or manually.

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Assures free flow of viscous materials.

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CPI News Briefs

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Processes

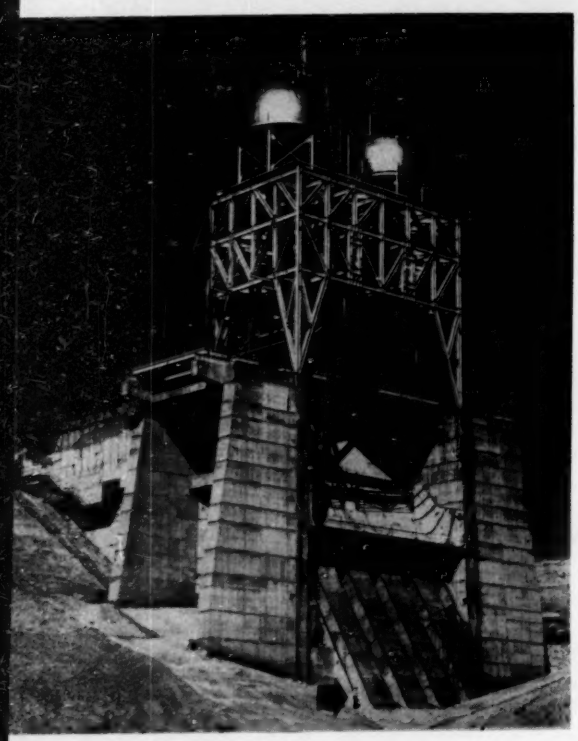
Isoprene production, by pyrolysis of 2-methyl-2-pentene, was described by Goodyear Tire & Rubber Co. at the recent A.I.Ch.E. meeting in Cleveland. Pyrolysis takes place in a cracking furnace at 1,300 F., in presence of steam and a hydrogen bromide catalyst. Distillation recovers isoprene along with methane and light gases for fuel; unreacted methylpentene is recycled.

Process starts with propylene, which is dimerized to 2-methyl-1-pentene by tripropyl aluminum catalyst. (Process' co-developer, Scientific Design Co., recently came up with another unidentified, catalyst for this step.) Isomerization over fixed-bed, acid-type catalyst produces the 2-methyl-2-pentene. Process is claimed to produce isoprene "at a cost equivalent to or less than that of butadiene."

Titanium-brazing process, for fabrication of high-temperature sandwich panels, has been developed by Convair Div. of General Dynamics, Fort Worth, Tex. Major innovation is a new brazing alloy consisting of silver, aluminum and manganese. (Lithium was found to be detrimental, has been specifically excluded from the alloy.) To eliminate other sources of contamination during brazing, copper and carbon steel aids have been replaced with stainless steel, and the graphite reference tool is now isolated from the brazing environment.

Hydrodesulfurization operating cycles for the Gulf HDS process have increased from 4-24 hours to 1-6 months over the past six years, reported Gulf engineers at the API Refining Div.'s meeting in Houston. Major portion of the improvement in on-stream time is produced by a new—and secret—catalyst that is more active and rejects coke-producing and metal-containing residue components.

To produce low-sulfur fuel oil, a 1,000-psi. HDS unit will operate 1- 4 months depending on the degree of hydrocracking. With a residue containing 5% sulfur, hydrogen consumption ranges from 300 to 750 std. cu. ft./bbl.



F-1 liquid-fuel test stand: man-in-space program gains momentum

National Aeronautics and Space Admin. and Rocketdyne Div. of North American Aviation, Inc., are ready to test the 1-5-million-lb.-thrust F-1 rocket engine—designed to spurt a man into space on liquid fuel—at Edwards Rocket Site, Calif. Shown is Test Stand 1-A of the $15-million complex, a concrete-and-steel behemoth towering 250 ft. above the Mojave Desert (arrow points at man).

Plants

Du Pont's polyethylene capacity will be boosted to nearly 400 million lb./yr. in the third quarter of 1962, when a new high-pressure unit comes on stream at the firm's Sabine River Works near Orange, Tex. Installation will turn out 50 million lb./yr. of high-pressure polyethylene and Du Pont's new vinyl resin, a copolymer of ethylene and vinyl acetate.

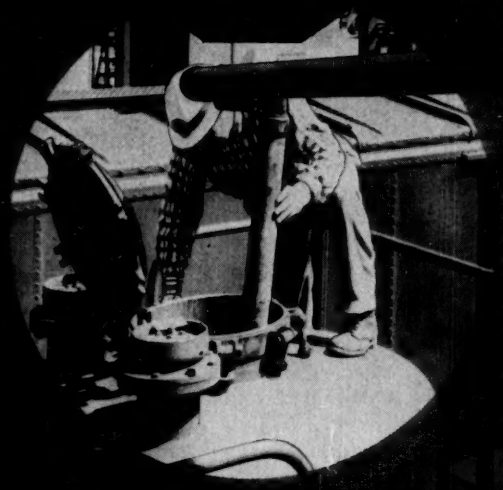
Brush Beryllium Co. is more than doubling its 12,000-lb./mo. potential (to 30,000 lb./mo.) for beryllium metal at Elmore, Ohio. The $6-million project is due on stream this summer.

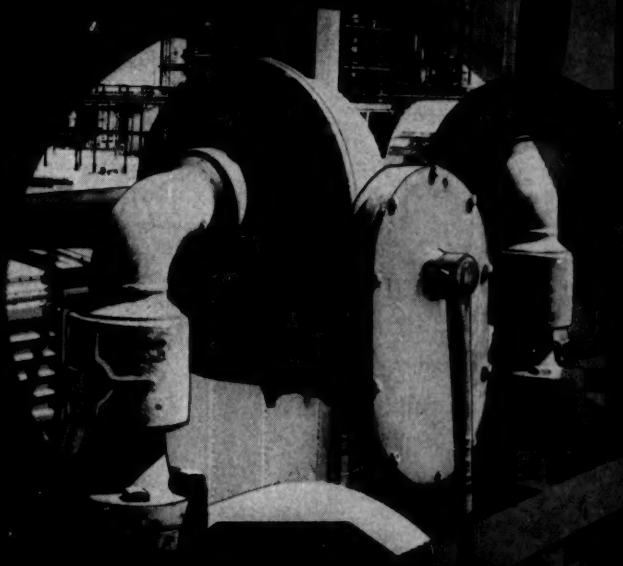
Anaconda Aluminum Co. has begun operating its Columbia Falls, Mont., aluminum plant at full capacity for the first time since July 1959. In announcing reactivation of the remaining 30 idle reduction cells in a bank of 240, executive vice president Mord Lewis said: "While there has been some improvement in shipments since the first of the year, profits have not materially improved. Consequently . . . every effort must be made to achieve lower costs [by higher production]." Two weeks ago,

CPI News Briefs continue on page 274

HE'S SAFE...

even on the tank car...





with

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ADDED SAFETY is an important benefit when you equip your loading rack with the only gear-driven swivel joint on the market. No danger of the operator slipping on wet or icy decking while pulling down a loading arm. No chance of arm dropping or rising unexpectedly to spill hot or caustic products. No counterbalance arms, cables or pulleys to endanger clearance on the platform. The entire loading operation is constantly controlled by this easy-to-crank joint.

TROUBLE-FREE SERVICE offers an equally important advantage. This gear-driven swivel joint incorporates all the proven features of C-E's popular US-Type Joint. It breaks like a union for quick, easy repairs on location without special tools. No need to disturb bearings when repacking. Wide-spaced bearings and non-split races last longer and permit greater foot/pound loading. Separate races can be reversed easily to double their life.

C-E Gear-Driven Swivel Joints are available in 2, 2½, 3 and 4 inch sizes — styles 3, 4, 5 and 6 — in mild steel or with stainless steel wettable parts.

For more years of service, less maintenance expense and a safer loading rack, equip it entirely with Continental-Emsco's Gear-Driven Swivel Joints. There's a size and type to meet every requirement.

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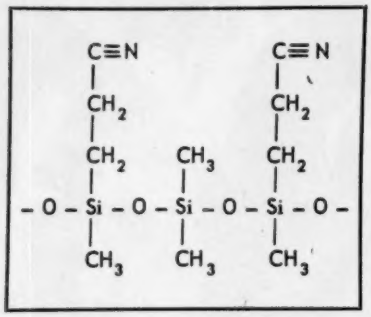


Nitrile silicones

Experimental silicones gain unusual solubility properties from high polarity of nitrile group.

By grafting nitrile groups to dimethyl polysiloxane, General Electric has boosted the polarity of silicone fluids, thus making them more solvent-resistant and electrically more conductive.

Pale yellow to water white in color, the tradenamed N.S. (nitrile silicone) fluids, unlike normal silicones, are insoluble in nonpolar solvents such as aliphatic and aromatic hydrocarbons, and soluble in certain polar solvents such as alcohols, ketones and ethers.

But, in general, an increase in the nitrile content corresponds to a decreased solubility of N.S. fluids in most solvents.

This property, combined with low surface tensions on the order of 23-26 dyne/cm. (dimethyl silicones have approximately the same surface tension range), makes these new fluids valuable in formulating solvent-resistant lubricants and greases, and suggests their possible use as antifoam agents in petroleum and hydrocarbon systems. Other applications: antistatic agents, plasticizers, components in polish formulations.

Where normal silicones have a volume resistivity in the range of 10^{13} to 10^{14} ohm-cm., N.S. fluids are somewhat more conductive and can be formulated with volume resistivities of 10^{9} ohm-cm.

They are also reported to be thermally stable for long periods at 300 F., won't hydrolyze or decompose in boiling water, and keep a fairly constant viscosity with change of temperature. Their viscosity-temperature cofficient (0.716 to 0.870) compares favorably with that of a good petroleum oil (0.750).

Still experimental, N.S. fluids are available in four grades, with nitrile content of 3 to 23 wt.%. Prices range from $11 to $16/lb., depending on the grade.—**General Electric, Waterford, N. Y. 108A**

Polyethylene latex

Emulsion polymer finds applications in textiles, paper and polishes.

The uniform particles above, 2,000 times smaller in diameter than a human hair, are solid particles contained in the first commercial polyethylene latex, to be available late in 1961.

Tradenamed Poly-Em, this latex will initially have a great impact in markets where emulsions of low molecular weight polyethylene waxes (produced as solids that must be emulsified before use) are the only presently available materials. In contrast to these wax emulsions, which contain no more than 30% solids, the new 40% solids latex is said to produce harder, tougher and more flexible films because of its higher molecular weight.

Spencer Chemical expects that these physical properties will expand textile, paper and polish applications now serviced by emulsifiable polyethylene.

In textiles, for example, Poly-Em acts as a softener in wash-and-wear fabrics and is compatible with many thermosetting resins and textile catalysts. Because of the wide choice of molecular weights available, it can be used to give a variable feel to fabrics.

Coatings laid down on paper give good moisture protection and can be printed and heat-sealed satisfactorily. According to Spencer, such coatings are being considered as replacements for extruded and laminated polyethylene coating on paperboard and breadwrapping stock. The latex is also being evaluated in the paper industry as a beater additive and as sizing.—**Spencer Chemical Co., Kansas City, Mo. 108B**

Thioacetic acid

Compound is an intermediate in manufacture of resins, pesticides, rubbers.

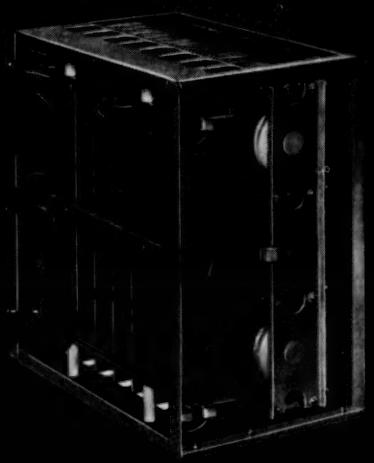
Thioacetic acid (CH_3COHS), a pale yellow liquid usually synthesized by heating glacial acetic acid and phosphorus pentasulfide, is now produced in semicommercial quantities at 95% minimum purity.

Characterized by its pungent, tear-producing odor, this acid has a long list of potential applications, as an intermediate in making mercaptomethyl polyamides, synthetic resins, pesticides, esters, and additives for rubber and oils.

As a rubber additive, for example, a small amount of thioacetic acid decreases the crystallization of rubber at low temperature without appreciably affecting the brittle point. Thioesters derived from this acid are also used as plasticizers or modifiers of synthetic rubber.

Vinyl thioacetates and the diester obtained by reacting thioacetic acid with glycol monoester can be polymerized to make resins; other thioesters could be used in ore flotation, dyes and lube oil additives.

Product is available in 1-, 5- and



Electronic air cleaning traps the expensive dirt

Minute particles of dust, dirt, smoke and bacteria...of less than 1 micron in size...pass right through mechanical filters. This is the dirtiest airborne dirt. The most expensive dirt. It soils walls, merchandise, lighting fixtures. Wears out moving parts. Shorts out motor windings. Contaminates foods, drugs, paints, chemicals. Causes malfunctions in electronic and precision equipment. Ordinary mechanical filters cannot trap this dirt.

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55-gal. drums at prices ranging from $1.65 to $1.25/lb.—**Stauffer Chemical Co., New York.** 108C

Teflon

Fluorocarbon resin to move into surface coatings and insulation.

Teflon FEP resin, available since February 1960, can now be obtained as a dispersion or as formulated spray finishes.

According to Du Pont, Teflon TE-9500 FEP dispersion should find acceptance as a Class H impregnant and surface coating for wire, cable and component insulation because it provides low permeability coatings, high dielectric strength in thin films, excellent heat sealability and may be fused at lower temperatures than dispersions of older Teflon resins.

Teflon FEP resin deposited by the TE-9500 dispersion can either be sealed to itself or to wire insulation, films, or massive shapes, made from FEP or TFE fluorocarbon resins.

Test marketed at an introductory price of $12/lb. (of solid), TE-9500 is a water dispersion with a solid content of 6.5 lb./gal.

Two Teflon FEP spray finishes are also available: 851-454 enamel green and 852-401 clear. These new finishes may be fused at temperatures of 575 to 625 F.—a distinct advantage over older spray finishes when working with relatively soft aluminum and copper alloys. —**E. I. DuPont de Nemours & Co., Wilmington, Del.** 110A

Textile softener

Small amounts of cationic agent improve fibers' tear strength.

Avitex Y, a yellow, viscous liquid succinctly identified as a quaternary fatty acid amine, disperses readily at 100 F. in water, and acts as a cationic softener on textiles and various resins.

According to Du Pont, it has a high degree of substantivity (doesn't need a mordant) at concentrations of 0.1-1.0% for cotton, rayon and nylon, and also gives antistatic protection to hydrophobic synthetic fibers.

Stable up to 140 F., Avitex Y becomes a nonpourable paste at 50 F., but turns to a liquid at 70 F. Although it causes slight shade changes in selected vat and fast-to-light direct dyes, it does not seriously reduce fabrics' lightfastness. Treated fabrics have higher tear strength and won't yellow when exposed to heat, light, ozone or to oxides of nitrogen found during application or in storage.

This softener can be applied alone or with starches, gums, thermosetting or thermoplastic resins. —**E. I. Du Pont de Nemours & Co., Wilmington, Del.** 110B

Butyl lithium

Suspended in wax, compound is easy to handle and inexpensive to ship.

Butyl lithium, an organometallic that has aroused interest particularly as an effective catalyst in stereospecific polymerizations of isoprene and butadiene, can now be handled without hazards of burns, fires or explosions.

By suspending butyl lithium in a specially blended paraffin wax, Lithium Corp. of America has successfully tamed this compound while keeping intact its catalytic punch.

Formerly, this chemical was available only in hexane or heptane solutions in concentrations up to 25% by weight. Such solutions were pyrophoric (flammable) in air, reacted with all forms of water (i.e., with atmospheric moisture and water in human tissue), and required therefore special shipping and unusual precautions in use.

But the new solid butyl lithium, cast in sticks of 1-in. dia. × 5-in. length, does away with all handling and shipping problems; it can be cut in open air and won't ignite when immersed in water. And even though the solid has a higher concentration of butyl lithium (30%), if exposed to a flame, it burns slowly and the fire can be easily put out.—**Lithium Corp. of America, New York.** 110C

Copolymer emulsions

Vinylpyrrolidone copolymers make tough, dye-receptive films.

Vinylpyrrolidone is branching away from the drug and cosmetic field as a copolymer with either ethyl acrylate or styrene in the new Polectron series of water emulsions.

According to the manufacturer, these emulsions are unusually

Newsworthy Chemicals

Page number is also reader service code number

Nitrile silicones exhibit unusual solubility properties.....108A
Polyethylene emulsion finds applications in textiles, paper.....108B
Thioacetic acid is produced in semicommercial quantities.....108C
Teflon dispersion can be used in surface coatings.....110A
Quaternary fatty acid amine acts as textile softener.....110B
Butyl lithium suspended in wax can be safely handled.....110C
Vinylpyrrolidone copolymers make tough, dye-receptive films.....110D
Zincating at lower salts concentration is now possible.....112A
Epoxy resins become flame resistant if combined with amines.....112B
Epoxy-novolac resin can be crosslinked with anhydrides.....112C
Ammonium metavanadate is now produced at 99.9% purity.....112D
New aluminum tinting pastes speed up colorant dispersions.....112E
Phenolic resin goes into production of shell molds and cores.....112F
Urea-formaldehyde concentrates now come in 85% solids content...112G
Ceramic adhesive operates up to 2,600 F.....124H
Rubber adhesive adheres to metals and plastics within minutes.....112I
Calcium silicate-asbestos fiber insulates pipes up to 1,200 F.....112J

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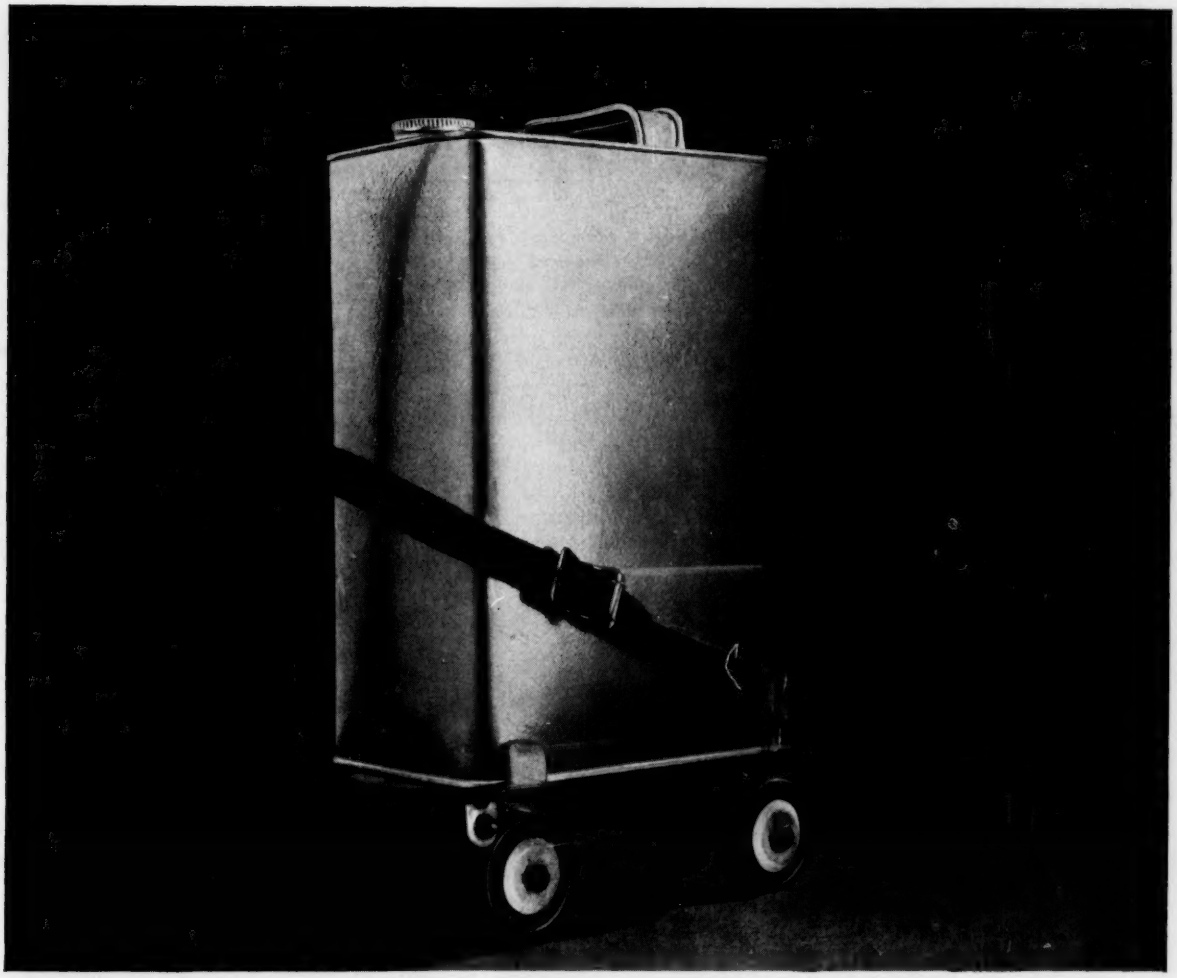

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Sodium Borohydride Treatments Stretch The Useful Life Of Glycols, Cut Your Costs!

This is an economy angle that's important to consider. Sodium borohydride gives important new "life" to glycols and polyglycols that are contaminated with trace carbonyl impurities . . . quickly, without any complicated reprocessing. Just add small amounts of sodium borohydride powder — or liquid solution (SWS). Within a short time, in some cases less than an hour, most of the unwanted carbonyl is reduced to the alcohol*, like this:

$$NaBH_4 + 4RCHO \xrightarrow{2H_2O} NaBO_2 + 4RCH_2OH$$

If you manufacture glycols, it will pay you to improve the purity of your product by adding sodium borohydride directly to the process stream — or, by using sodium borohydride pellets for fixed bed purification. Doing it either way will give you the purity you want — without adding any significant cost to your overall process!

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stable. They produce films having excellent adhesion, to textiles, paper and glass fibers, and high receptivity for dyes—desired in nonwoven fabric binders and rug backings. Because these films are tough and insoluble, they look promising as metal primers and top coatings on wood; curing takes only one hour at 212 F.

The films are insoluble in water, ethyl alcohol, ethyl acetate, acetone, methyl ethyl ketone, benzene, carbon tetrachloride, heptane and dioxane. In addition, they claim excellent freeze-thaw stability, shear stability, acid and salt tolerance.

Although their current prices range from 35 to 45¢/lb., Polectron emulsions should become available at reduced prices by the end of this year.—**Antara Chemicals Div., General Aniline and Film Corp., New York.** **110D**

Preelectroplating bath

Zincating at lower salts concentration is now possible.

When used after cleaning and acid dipping, an improved zincating bath, composed mostly of zinc oxide and sodium hydroxide, simultaneously activates aluminum substrates and deposits a thin, uniform zinc film that can be electroplated with copper, nickel or other deposits having excellent adhesion to aluminum.

The new zincating bath, Alumon D, is made up at a concentration of only 1 lb./gal. Compared with the viscous 4 to 5 lb./gal. conventional zincate bath, it penetrates more readily into grooves, screw threads and blind holes, and minimizes carry-over of zincate (ZnO and NaOH) into subsequent plating baths.

Besides the usual zinc oxide and caustic components, Alumon D contains some undisclosed complexing agents that prevent harmful attack on aluminum and give a more efficient bath at lower concentrations. Immersion periods in the new bath vary from ½ to 2 min. at room temperature.

Product is available as a powder ($0.73-1.10/lb.) or as a liquid ($3.75-4.60/gal.) and may be used interchangeably.—**Enthone Inc., New Haven, Conn.** **112A**

Briefs

A new epoxy resin has been given flame resistance by combination with undisclosed aromatic amine or anhydride hardeners. Called Bakelite ERL-0625, it is suitable for hot-melt castings and dry lay-up laminating systems. It is semisolid at room temperature but requires only moderate heating to about 130 F. to become a pourable liquid for casting systems, and 150-155 F. for laminating systems. —**Union Carbide Plastics Co., New York.** **112B**

Epoxy-novolac resin, Isochemrez 460, is a low-viscosity liquid that can be cured to a tightly cross-linked system upon addition of hardeners such as metaphenylenediamine eutectics or anhydrides. It can be used for making adhesives that are stable from −60 to 280 F.; high-temperature potting, casting and coating compounds; in manufacture of printed circuit board and chemically resistant piping.—**Isochem Resins Co., Providence, R. I.** **112C**

Ammonium metavanadate, a pale-yellow crystalline powder, has now been improved to a specification purity of 99.9%, required for the preparation of vanadium-containing oxidation catalysts. The new grade is also important in glass colorants, inks, ceramic enamels and paint driers.—**Union Carbide Nuclear Co., New York.** **112D**

Aluminum tinting pastes Nos. 225 and 226 can produce truer yellows, golds and reds because of closely controlled particle size distribution. Increased wetting properties of the new pigments make possible reduction of dispersion time in preparing tinting bases. They are also reported stable with organic and inorganic colorants. — **Aluminum Co. of America, Pittsburgh.** **112E**

Phenolic resin Bakelite BRS-5575 yields a fast curing, cold-coated sand suitable for producing both shell molds and cores. This resin (fusion point 215 F.) is recommended where a short to medium-flow, fast-curing resin is required, and for applications in which freedom from shell warpage is difficult to achieve. — **Union Carbide Plastics Co., New York.** **112F**

Urea-formaldehyde concentrates, UFC 7626, 7147 and 8545, differing mostly in solids content (71 to 85% minimum), are now available for manufacture of many types of urea-formaldehyde resins used in plywood adhesives, furniture, paper, and textile and protective coatings. — **Hercules Powder Co., Wilmington, Del.** **112G**

Ceramic adhesive, Melbond CA-100, has maximum service temperature of 2,600 F., after a cure of only 250 F. Product attains high mechanical strength and won't flake or disintegrate during use. It adheres well to alumina, pyrophyllite, Foamsil, graphite, zirconia and Alundum firebricks. —**Melpar Inc., Falls Church, Va.** **112H**

Synthetic rubber adhesive Bostik 1142 allows parts assembly within two to five minutes after application. It adheres to metals, rubbers, phenolics, polystyrene, fiber glass, cork, leather, nylon, urethane sponge and enameled surfaces.—**United Shoe Machinery Corp., Boston.** **112I**

Calcium silicate and asbestos fiber are the components of Zebra, a multilayer sectional pipe insulation that can be used up to 1,200 F. The multilayers are crush-resistant under the loads created by workmen who might need to walk on, or place ladders against, covered runs of pipe. — **Keasbey & Mattison, Ambler, Pa.** **112J**

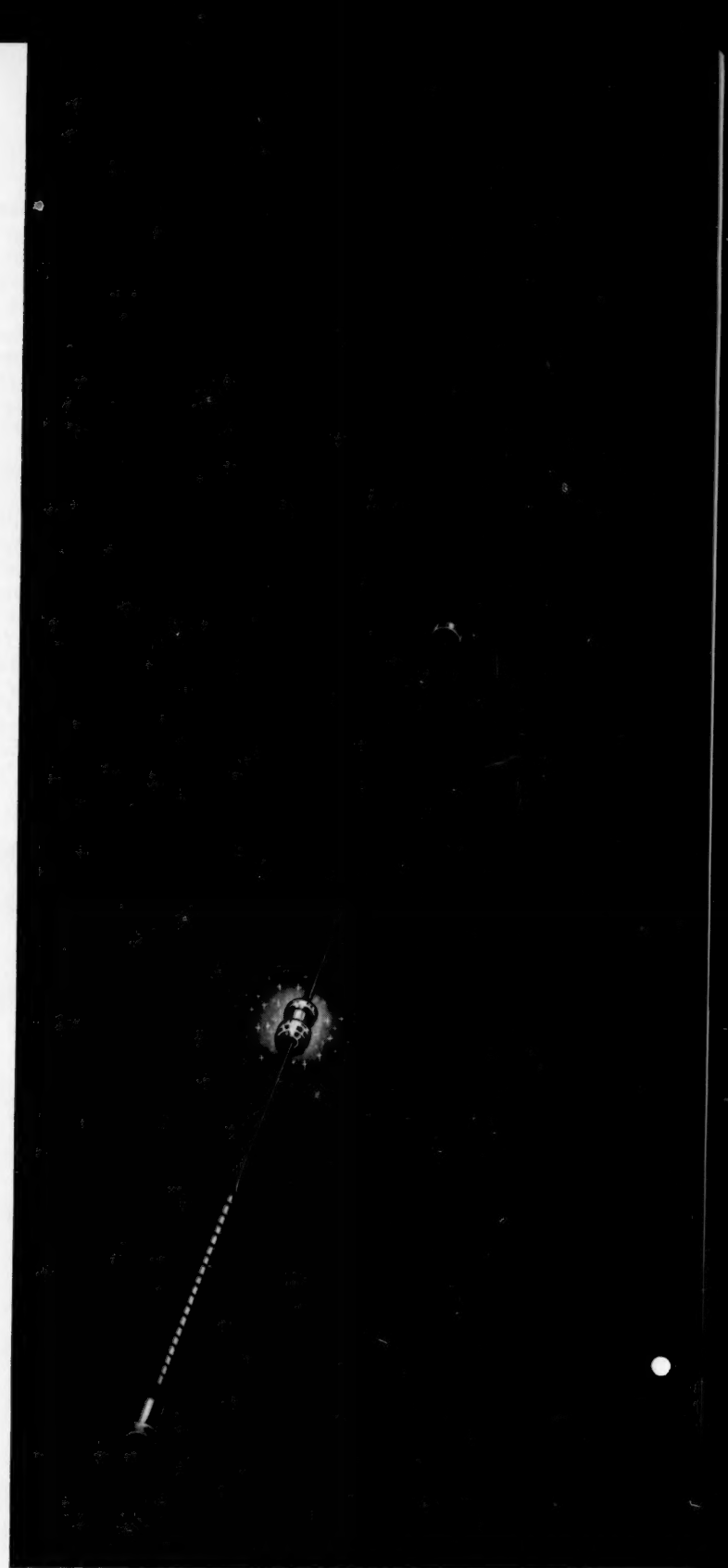
For more information about any item in this department, circle its code number on the Reader Service Postcard (Page 317)

A step beyond silicone dampening of thermometers

This is a special dampening bearing, used just above the bimetal element in Rochester industrial thermometers. It is a precision machined part which serves several needed dampening functions: it further dampens the bimetal shaft; it helps to prevent coil unwinding and pointer oscillation; it serves as a better guide for perfect shaft alignment within the tube.

The primary reason for dampening bimetallic dial thermometers, of course, is to preserve accurate calibration, especially on the lower temperature ranges where a thinner bimetal element is used. The combined use of a special dampening bearing *and* silicone makes Rochester thermometers extra resistant to shock and vibration. You get this *only* in Rochester industrial thermometers.

Write, wire or phone—tell us your requirements for indicating and control instruments—let Rochester Instruments engineering skill go to work for you. American-Standard Controls Division, ROCHESTER INSTRUMENT PLANT, 113 Rockwood Street, Rochester 10, N.Y.



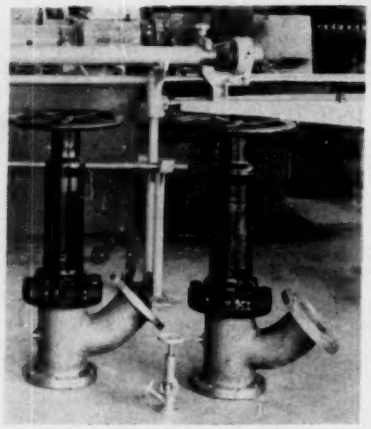
PROCESS CONTROLS

Detroit Pressure Control Switch

Norwood Strain Gauge Pressure Pickup (to 60,000 psi.)

AMERICAN-Standard

CONTROLS DIVISION



Free-flow drain

Large piston valve prevents plugging in 6-in. tank outlets.

Freedom from plugging by settled solids has now been extended upward from 4-in.-dia. tank outlets to 6-in. with introduction of the new 6-in. Strahman ram-type drain valve.

Design of the value is like those in the 1 to 4-in. sizes. In closed position, a piston or ram extends up into the tank, keeping the outlet free of solids.

To drain the tank, the piston is withdrawn into the bonnet, leaving a completely open passage for full free flow. On closing, the upward movement of the piston forces excess material back into the tank, thereby assuring a free-flowing discharge when the value is reopened.

Valve packing consists of resilient rings around the piston, above and below the discharge outlet. Close fit between piston and the internal area of the body prevents accumulation of material that could harden and freeze the valve. Construction is offered in a wide range of alloys, including Hastelloy and titanium.

Strahman's offering of the larger-size valve is reported to stem from new production facilities. Present delivery times of 6-8 weeks may soon be cut in half as production increases. The 1 to 4-in. valves will be available within a week.—**Strahman Valves, Inc., Florham Park, N. J.** 114B

Packaged computer

Compact unit serves for data processing, problem solving.

Office-desk sized, a new computer is said to perform many functions that previously required bulkier and more costly equipment. Called Control Data 160-A, the device is an expanded version of a previous unit.

The basic computer is equipped with a magnetic core memory of 8,000 12-bit computer words (memory is expandable to 33,000 words), buffered input and output, program interruption and a list of 91 instructions. A variety of peripheral equipment can be added to meet expanded computer requirements.

Applications for the unit include commercial and scientific data processing, engineering problem solving, offline data conversion, and industrial control applications. The 160-A may be purchased for $90,000 or rented for $2,250/mo.—**Control Data Corp., Computer Div., Minneapolis.** 114C

Alarm rotameter

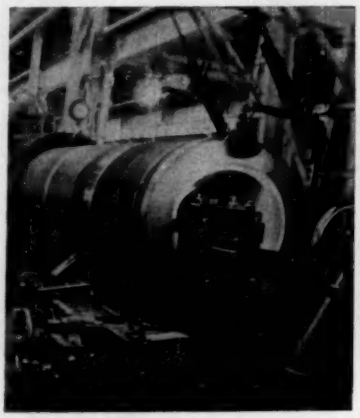
Compact unit has indicating element and alarm system.

Newly designed to save installation space, a combination rotameter and alarm system is included in one housing. In previous designs, the tube, indicating element and alarm system were mounted separately, one above the other.

Unit contains a metal-tube rotameter with visual indicator, and an alarm system consisting of a magnetic indicator and alarm switches, all mounted in a weatherproof housing.

In operation, alarm switches are set for desired maximum and minimum flow. Higher or lower flow will cause the switches to activate a signal light, bell, other alarm device or a control mechanism.—**Schutte & Koerting Co., Cornwells Heights, Pa.** 114D

Swords into plowshares: guns into pressure vessels



Once a powerful 16-in. naval gun, this multilayer 103-ton barrel is being converted into a 30,000-psi. coded pressure vessell. A 20-ft. length of the breech end is machined to 18-in. I.D.; the breech is modified for quick-opening entry, and the muzzle end is sealed semipermanently with a threaded plug and a cup-type seal. Vessel is one of many prepared from surplus gun barrels. — **National Forge Co., Irvine, Pa.** 114A

continued on page 116

ALEMITE
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Lubrication is a vital production tool—proven as the means to step up production . . . cut downtime . . . increase machine life and efficiency! A lubrication system should be as carefully selected as any other major production tool in your plant. Investigation will show that the finest plan is Alemite Barrel-to-Bearing Lubrication.

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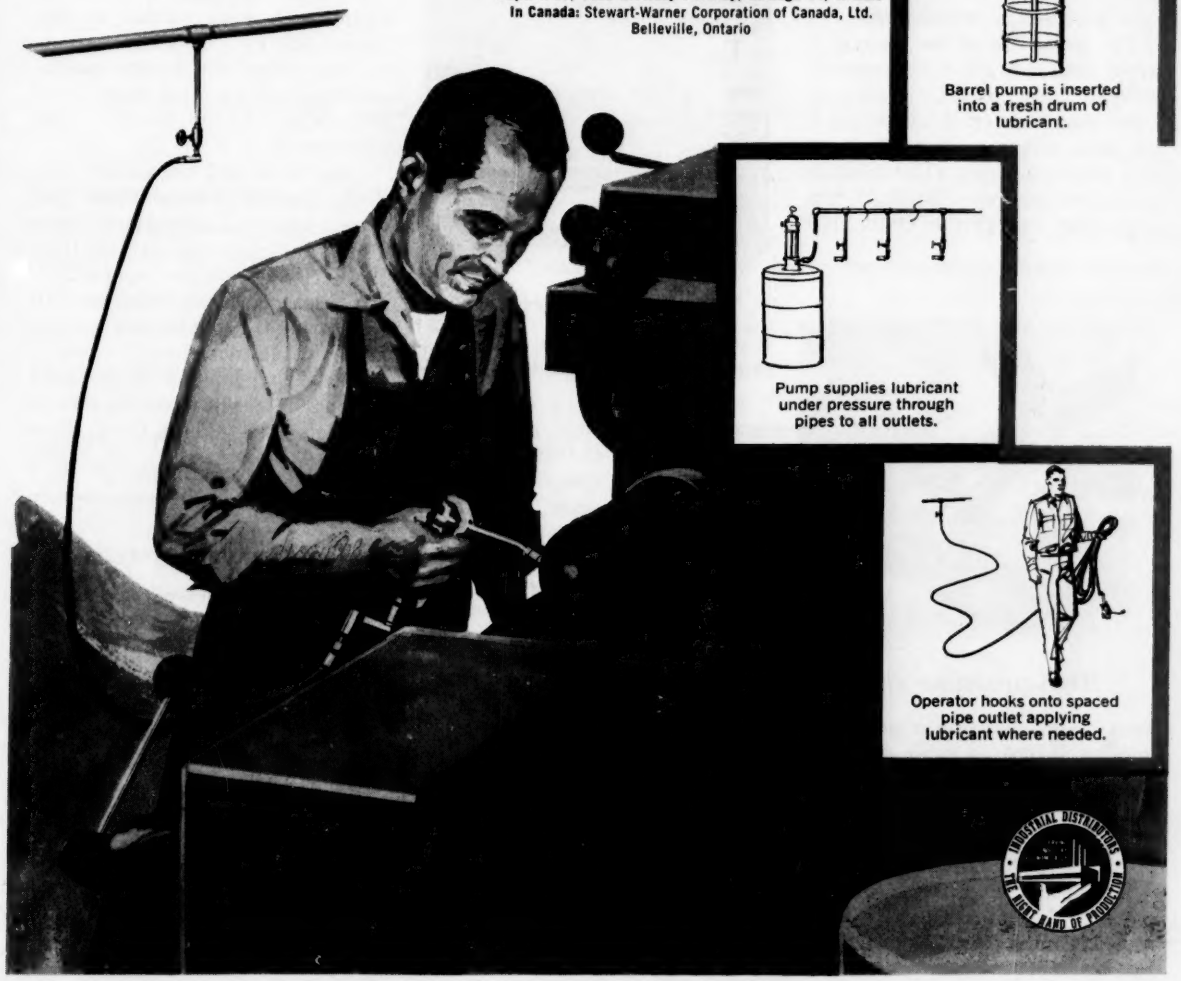

Barrel pump is inserted into a fresh drum of lubricant.

Pump supplies lubricant under pressure through pipes to all outlets.

Operator hooks onto spaced pipe outlet applying lubricant where needed.

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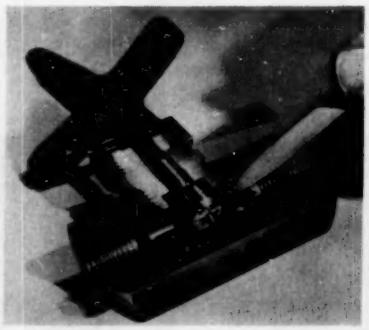
THE RIGHT HAND OF PRODUCTION

Level-control valve

Float-actuated plunger is designed to prevent leaks and chatter.

For level control of cooling towers, tanks, reservoirs—any location where a constant liquid level is required—a ½-in. bronze control valve uses a float to actuate a plunger. A rachet and thumbscrew connection on the actuating arm and float rod holder permit easy positioning of the float.

The lower end of the plunger is fitted with a heavy-duty neoprene washer, said to help eliminate leaks and chatter. Unit is available with either a 12-in. float rod or a chain-and-float. Float is either plastic or copper.—**Mansfield Sanitary, Inc., Perrysville, Ohio. 116A**



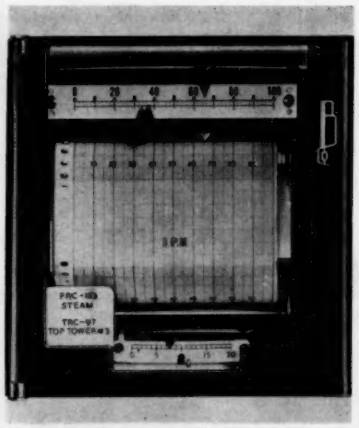
High-pressure valve

Seat compresses into a positive-sealing O-ring as valve closes.

This valve forms an O-ring seal when it is closed. A Teflon seat is compressed to form a Teflon-to-metal seal. Housed in a stainless steel swivel cage attached to a free-turning stem, a portion of the seat is forced from the cage as the valve stem is screwed down to a closed position. The swivel design is said to eliminate galling.

Stainless steel construction assures that the valve will stand up in corrosive service. Nature of the seat design renders the valve leakproof, despite erosion or interference by foreign matter.

Rated to 10,000 psi., valve can be opened and closed easily under pressure. When closed, the stem packing can be replaced without removing the valve from the line. Sizes available: ¼-¾-in.—**Clayton Mark & Co., Evanston, Ill. 116B**



Pneumatic receiver

Rectilinear coordinates on 4-in. chart enhance readability.

Newly designed, a series of 4-in.-chart pneumatic receivers is said to be easy to install, use and maintain. The chart is mounted on a removable drive, to facilitate chart changing and allow access to the front end of the chassis while it is still in the case.

Nine models are available to meet a variety of control requirements. Up to three inking systems may be provided; they can be refilled from the front of the case. Pointers are brightly colored and distinctively shaped.

Switching functions have been simplified so that to switch from one to another the operator simply lines up the proper pointers (indicated in color) to obtain the desired function.—**The Bristol Co., Waterbury, Conn. 116C**

Portable pump

Hand-operated diaphragm unit is self-priming, handles slurries.

Said to handle virtually any material that will flow, a self-priming diaphragm pump is completely portable, can be quickly set up for emergency or special pumping duty. It pumps liquids containing any size solids that can pass through the 2-in. suction and discharge connections.

By handling up to a gallon of liquid with each stroke, it can move 1,800 gal./hr. with one person operating the pump handle, which provides a large mechanical advantage. The unit has a suction lift of 25 ft.

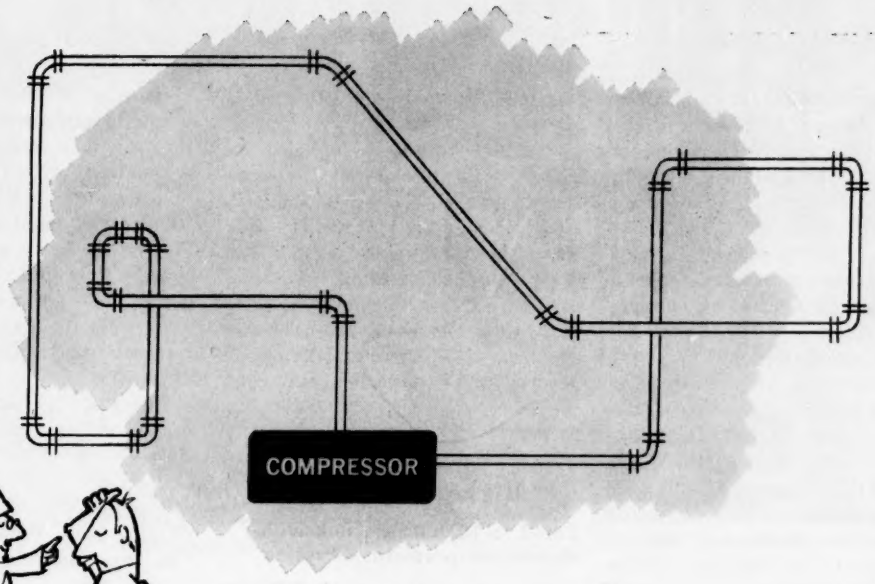
Diaphragm and valves are synthetic rubber formulations, designed to give long service in ordinary and corrosive service. Inlet and outlet fittings are regular 2-in. pipe threads for convenience in connecting the unit to pipe or hose. Made in aluminum, bronze or stainless steel, the pump is designed with the inlet either on the side or the bottom. — **Edson Corp., New Bedford, Mass. 116D**

Computer system

Peripheral equipment saves computing time in central calculator.

Assuming many routine tasks, a system of peripheral computer equipment can add as much as 25% to the time available for actual computation in the central computer. The system lends itself to expanded processing as demand increases.

Included are a central processor with a high-speed core storage, a magnetic-tape unit with a transfer rate of 90,000 characters per sec-



when you discuss your compressor system, what does PAR mean to you?

THE WORD HAS MANY DEFINITIONS

PAR to the golfer means the number of strokes allotted per hole or for the round of golf.

PAR to the investor is the established nominal value of a security or certificate of stock.

PAR can be an amount which is taken as an average or mean... an average level, etc.

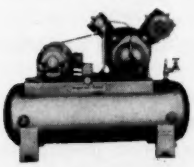
Possibly the only connotation you might place on PAR is the expression that it's either up to PAR or not up to PAR, meaning up to standard.

BUT THERE'S ANOTHER MEANING TOO

At Ingersoll-Rand Company we like to think of PAR in terms of a "PLANNED ANNUAL REVIEW" of a customer's air power system. The newest, most efficient air-operated devices are only as effective as the power that drives them, and usually low air pressure is the reason for equipment not functioning properly.

An Ingersoll-Rand AIRengineer will be happy to help you plan present or future air requirements and keep you abreast of the latest developments in tools and air systems. He will make sure you get the biggest dividend on your payroll dollars from a carefully PLANNED ANNUAL REVIEW of your air power system. Let us schedule a PAR for you now.

Air-cooled compressors 1/2 through 125 horsepower



Type 30 Compressors
1/2 through 20 hp
pressures to 250 psi

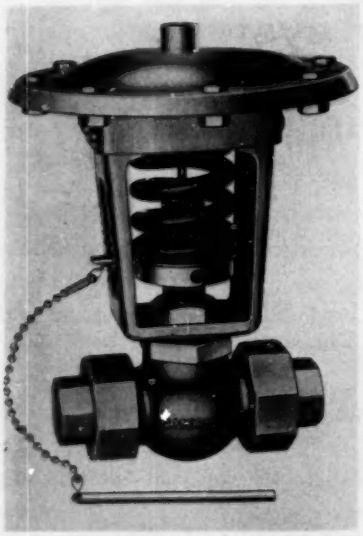
Type 40 Compressors
25 through 125 hp
pressures to 125 psi

Ingersoll-Rand
248A3 11 Broadway, New York 4, N. Y.

OTHER I-R COMPRESSORS TO 7500 HP—PRESSURES TO 5000 PSIG.

ond, a card reader that handles 2,250 cards per minute, a high-speed printer and a card punch. Called 2400, the system is used in conjunction with the existing Philco 2000 computer.

Duties of the processor include stored-program functions such as editing, search and select, sorting, and data translations. It does all input-output functions for the 2000, combining this processing with a minimum of control circuitry for each device. There are no programmed plugboards. Working in parallel, the 2000 and 2400 systems can be coordinated so that each handles portions of the job best suited to its abilities.—**Philco Corp., Philadelphia.** 116E



Pressure regulator

Friction-free packless valve permits quick response to pressure change.

Suitable for controlling pressure of steam, air, water and gases that are noncorrosive to bronze, iron or neoprene, this regulator has a friction-free packless valve that responds immediately to small pressure changes.

Available in single- and double-seated designs, the unit is sized from ½ to 2 in. Rated to 250 psi., its diaphragm is made of flexible Neoprene-impregnated nylon. The upper diaphragm housing assembly is stainless steel, lipped over to protect the outer edge of the diaphragm.—**Manning, Maxwell & Moore, Inc., Stratford, Conn.** 118A

For more information about any item in this department, circle its code number on the Reader Service Postcard (Page 317)

High-pressure gage

Rated to 10,000 psi., unit withstands overpressure, vibration

Instead of the usual "C"-type Bourdon tube, this high-pressure gage employs a helical-wound tube, the end of which rotates as the pressure increases, to give a full 270-deg. dial indication. With no links, pivots, gears or other moving parts, the unit is said to be virtually impossible to wear out.

Over-all accuracy of ± ¼% was maintained for more than 100,000 pressure cycles in developmental tests. Simple nature of the pressure element helps the gage to maintain accuracy under extreme conditions of overload pressure, vibration, shock, or line pulsation. Bursting pressure is rated at more than three times the scale range.

Unit is equipped with a special sliding flange for flush or panel mounting. Case is anodized aluminum. — **American-Standard Controls Div., Detroit.** 118B

Level controller

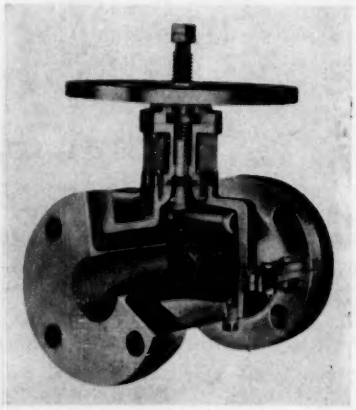
Instrument serves for toxic, corrosive and high-pressure duty.

Available with buoyant and displacer floats for specific-gravity, liquid- or interface-level applications, this instrument performs indication and alarm functions.

A transducer, called a magnetic position converter, translates the linear movement of a float into a rotary motion. In operation, a magnet attached to a float extension attracts the leading edge of an iron helix enclosed in a nonmagnetic stainless steel tube.

As the float and extension move vertically, the magnetic attraction causes the helix to rotate. A pointer and sensing cam attached to the helix also rotate; the pointer provides visual indication while the cam works through a pneumatic follower or other instrument to transmit level measurements.

The sensing cam normally produces an output signal that is linear to level change. Accuracy is said to be ±0.25% on instruments operating up to 800 F. and 40,000 psi.—**Brooks Instrument Co., Inc., Hatfield, Pa.** 118C



Pinch valve

Unit opens fully, even when line pressure goes below 10 psi.

Free of internal obstructions and cavities that can affect flow, this pinch valve permits straight-through flow in either direction at up to 98% of full-line capacity. A new design feature assures complete opening of the valve even when the operating pressure falls below 10 psi., according to the manufacturer.

Available in sizes from ¼ to 14 in. at a maximum pressure of 400 psi., valve can be furnished for hand, air, electrical or electro-

New Equipment continues on page 290

Above, a typical solvent manifold. Shell now offers five high boilers and 11 other solvents in economical mixed loads.

SOLVENTS:

Shell Chemical now offers 5 high boilers, 2 medium boilers, 2 low boilers, 4 latent solvents, 2 mutual solvents and 1 unclassifiable, all with mixed load savings

With the addition of three high boiling solvents—methyl amyl acetate and the completely new Pent-Oxone* keto-ether and Pent-Oxol* glycol ether—Shell now offers you a full formulating range with all the bulk price benefits of single-source supply.

Glance through these 16 solvents listed below. See how many you are using currently. If there are any you are not using, perhaps you would like samples of them.

In August, 1960, Shell Chemical introduced Pent-Oxone, a double-action keto-ether high boiling solvent.

At the same time Shell introduced Pent-Oxol, a glycol ether solvent with especial promise as a blush retarding, reasonably quick drying high boiler for nitrocellulose.

Now, to round out the high boiling line, Shell Chemical has added methyl amyl acetate.

5 high boilers

This brings Shell's list of high boilers to five. Pent-Oxone, Pent-Oxol, methyl amyl acetate, ethyl amyl ketone and diacetone alcohol.

2 medium boilers

Shell's major medium boiler scarcely needs an introduction. It's methyl isobutyl ketone.

Shell's second medium boiler is mesityl oxide, an unsaturated ketone with very strong solvent properties.

2 low boilers

Like methyl isobutyl ketone, Shell's two low boilers are industry standards: methyl ethyl ketone and acetone.

4 latent solvents

Shell's four latent solvents are ethyl alcohol, isopropyl alcohol, methyl isobutyl carbinol—an isomeric hexyl alcohol—and secondary butyl alcohol, a solvent for many natural resins, gums and oils.

2 mutual solvents

Hexylene glycol and tertiary butyl alcohol are excellent co-solvents for many immiscible substances.

Unclassifiable

Isopropyl ether is not so easy to put a tag on. It is an extractant for fine chemicals, a solvent for ethyl cellulose, and frequently is used to replace ethyl ether where a solvent of lower volatility is wanted.

Mixed load savings

These 16 solvents are all available in tank cars to drums from any of Shell's nine Industrial Chemical offices. Send for samples. And ask the man from Shell how you can save money through mixed load purchases.

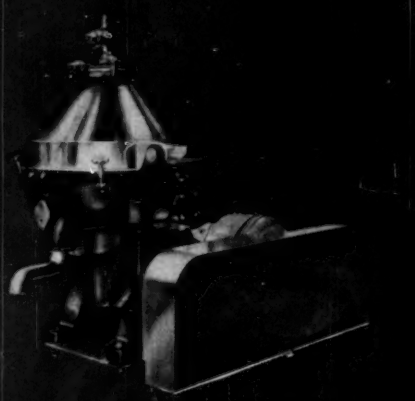
*Trademark, Shell Chemical Company

Shell Chemical Company

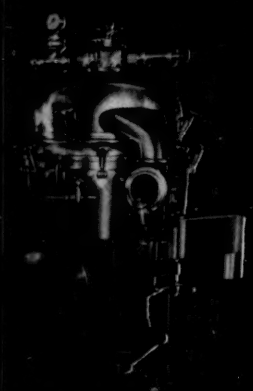
SHELL

Industrial Chemicals Division
110 W. 51 Street, New York 20, N. Y.

Centrifugal Spin and 3-D Bounce aid solids separation and classification in DE LAVAL SEPARATORS



SOLIDS ARE CONTINUOUSLY REMOVED



A GREAT RANGE OF SOLIDS

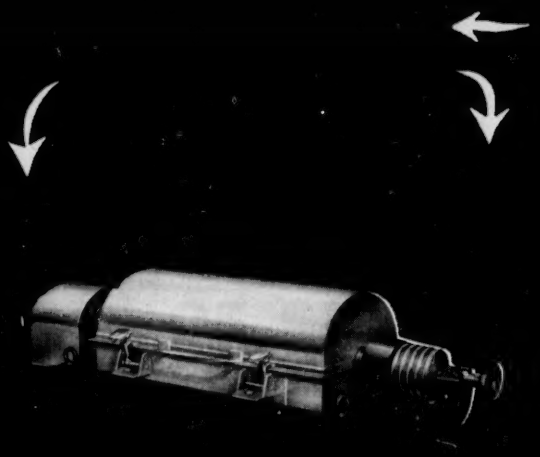
Solids separations problems ranging from clarification of murky liquids to solid classification are effectively solved by De Laval Process Equipment. These include special types of highly efficient disc-bowl centrifuges, conveyor-bowl centrifuges with high bulk-handling ability, and a unique type of classifying separator. Operation of these compact units opens new versatile possibilities in processing efficiencies and economies.

The Process Centrifuges described here are just a few from a complete line of industrial centrifugal separators. For full information on these, or the Syncro-Matic Separator, write us outlining your type of separation problem. Appropriate technical literature will be promptly sent.

THE DE LAVAL SEPARATOR COMPANY

Poughkeepsie, N. Y.
5724 N. Pulaski, Chicago 46, Ill.
201 E. Millbrae Ave., Millbrae, Cal.

DE LAVAL



SLURRIES UP TO 50% SOLIDS

CONTROLLED 3-D BOUNCE SPEEDS SCREENING

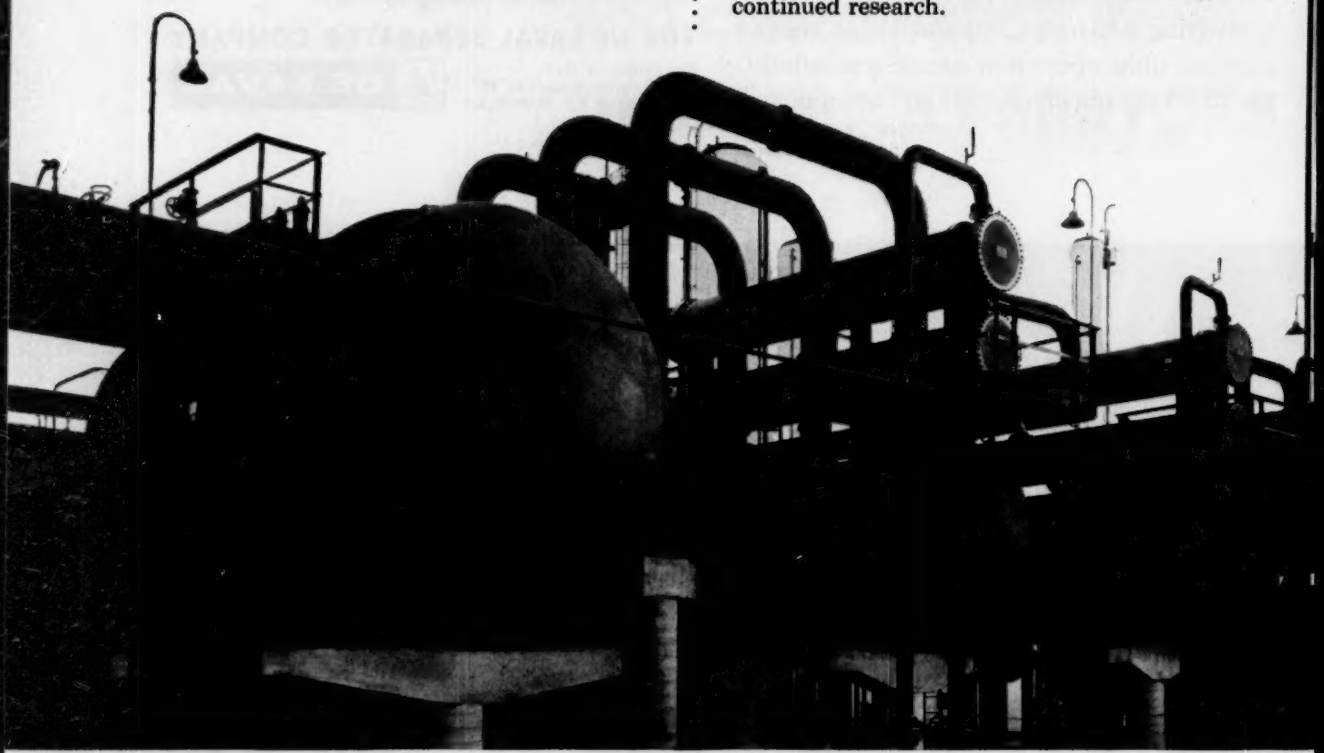
For Insulating · Sealing · Coating · Waterproofing

USE LION Nōkōrōde PROTECTION

A Complete, Proven Line

Do your structures need protection from moisture? High temperature? Low temperature? Corrosion? Escaping heat? Whatever your protection problem, there is a Lion Nokorode Coating designed to solve it.

Tough, durable Lion Nokorode Protective Coatings can be sprayed on regular or irregular surfaces faster than most coatings. They adhere at any angle, and change shape without rupturing. These coatings are constantly proved and improved throughout world-wide use and continued research.



Lion Nokorode Seal Kote protects vessels and pipes from corrosion in a modern chemical plant.

The Best Technical Information

While developing the complete line of Nokorode Coatings, Lion Oil and its parent company, Monsanto Chemical Company, also have developed the most complete file of technical information in the industry. Tell us your problem. We will send you the technical literature which applies. Just mail the coupon.

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Technical Booklet gives uses and specifications of Lion Nokorode Seal Kote and application techniques.

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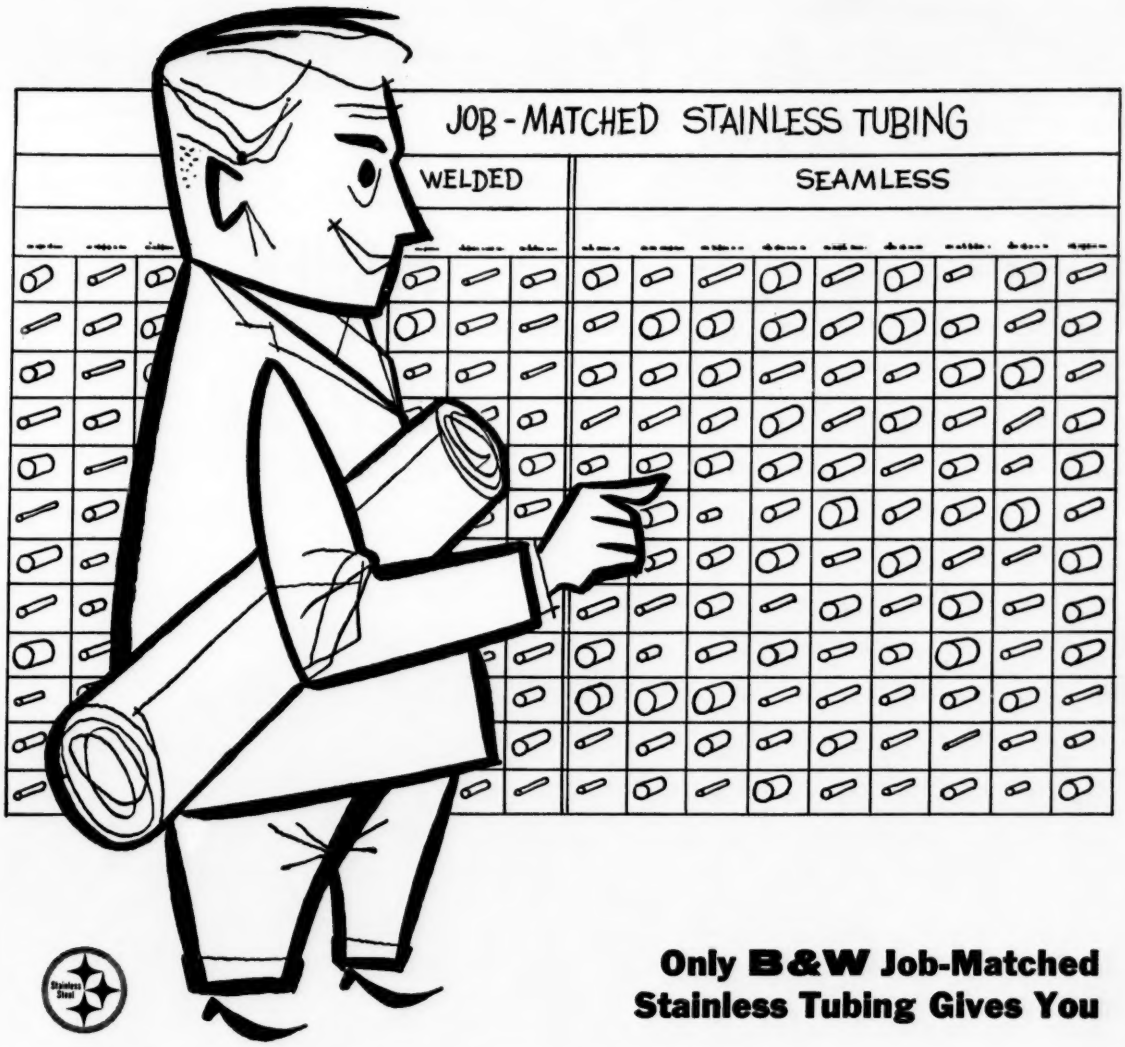

Only B&W Job-Matched Stainless Tubing Gives You

FULL-RANGE SELECTION OF SEAMLESS AND WELDED

Whatever your stainless steel tubing requirements, B&W has the right tube for the job.

Only B&W tubing offers you both seamless and welded in a complete selection of grades, sizes and lengths. It's job-matched with the right combination of properties, diameter and wall thickness to make bending, forming and other fabrication operations easier, faster, more economical. And you can rely on consistent quality and uniformity from tube to tube for freedom of design and long service life.

Make B&W your choice for stainless tubing. It's available at Steel Service Centers or through your local B&W District Sales Office. For Bulletin T-148, write The Babcock & Wilcox Company, Tubular Products Division, Beaver Falls, Pennsylvania.

B&W

THE BABCOCK & WILCOX COMPANY

TUBULAR PRODUCTS DIVISION

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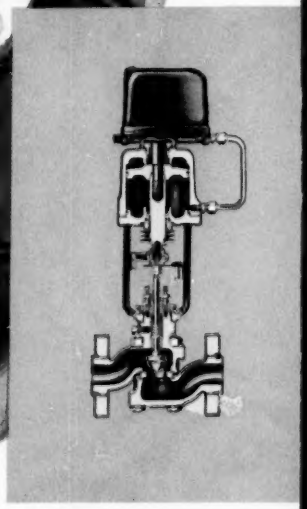
Seamless and welded tubular products, solid extrusions, seamless welding fittings and forged steel flanges—in carbon, alloy and stainless steels and special metals

Compact...Powerful...

FISHER
SERIES
470 P.O.P.

PNEUMATICALLY OPERATED PISTON



SPLIT BODY CONSTRUCTION

Type 470-Z Actuator with a Split body. P.O.P. is also ideal for three way bodies and large single port globe or angle bodies. Only Fisher gives you such a wide selection of actuator-body combinations.

Piston Actuator for Control Valves

does jobs that once required giant size equipment!

POWER—Thrusts up to 17,500 pounds available. Delivers same power in either direction at any point of the stroke.

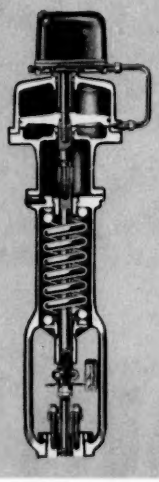
ACCURACY—Maximum Hysteresis 0.15% of stroke or signal. Repeatability 0.03% of stroke or signal. Resolution Sensitivity 0.02% of instrument signal.

SPEED—4 inches per second stroking speed with the Size 30. Size 60 provides 1.5 inches per second.

STABILITY—Built-in intermediate feedback causes proportional band of positioner to be broad while instrument changes are taking place, yet narrow when unit is not in motion.

Here's power plus in a small package! This compact Fisher 470 Series has its own positioner mounted integrally on top of the cylinder. Positioner receives any of the normally used pneumatic instrument signals. Then, without an air set, actuator utilizes the full potential of the available air or gas supply (up to 150 psi) to provide exceptional speed and power.

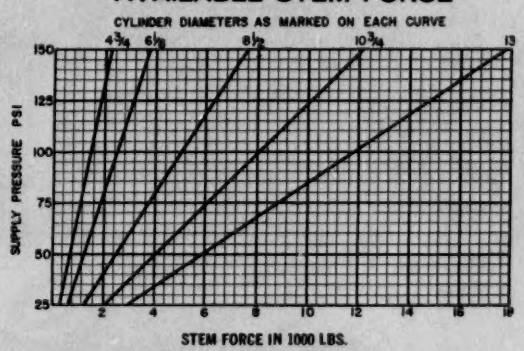
Series 470 is adaptable to virtually all types of valve bodies including butterfly valves. Easily reversible actuator can be changed in the field. Available in six basic sizes and can be supplied for travel up to 4". Basic actuator can also be furnished with a handjack, hydraulic snubber, pneumatic safety devices or as a spring return unit . . . **Write for Bulletin E470.**



BRACKET MOUNTED SERIES 480 P.O.P.

The versatility of Fisher's P.O.P. actuators is further highlighted in the bracket mounted Series 480. The Series 480 provides a compact, powerful actuator for the operation of butterfly valves, louvers, large rheostats and similar equipment found in many industrial applications.

AVAILABLE STEM FORCE



Besides the five basic sizes shown by the curves, a 17 inch cylinder can be supplied to provide thrusts of 12,000 pounds with a supply pressure of only 60 psi.

SPRING RETURN ACTUATOR

Type 473 Actuator with spring safety device. In event of a supply pressure failure control valve will move into the closed position. Also available with spring for return to open position in event of plant air failure.

IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD . . . CHANCES ARE IT'S CONTROLLED BY . . .

FISHER GOVERNOR COMPANY

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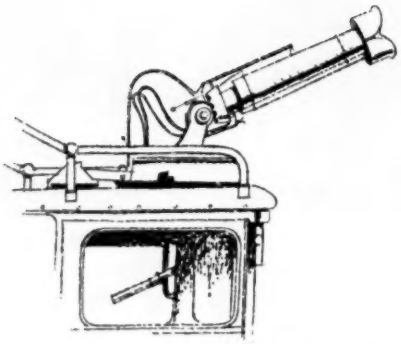
BUTTERFLY VALVE DIVISION: CONTINENTAL EQUIPMENT COMPANY, CORAOPOLIS, PA.

FISHER®

SINCE 1880



ROCKWOOD DELIVERS MORE FIRE FIGHTING POWER—

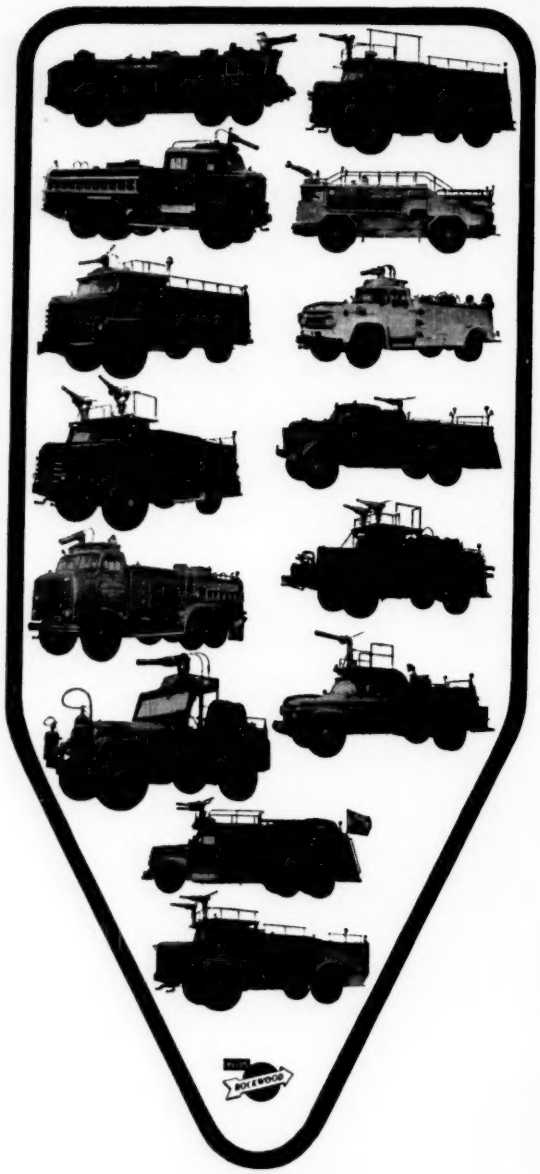
extinguishes faster

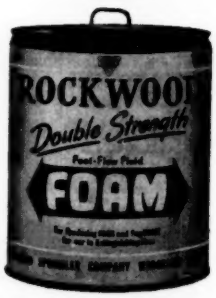
Rockwood specialty FOAM Fire-Truck equipment provides greater fire-fighting punch to meet any situation fast and make manpower more effective! Why? Because it adapts quickly to changing conditions . . . hits harder and faster.

There's volume and versatility to spare in Rockwood turret nozzles. They are immediately adjustable to fight fire four ways: with FogFOAM — Solid FOAM Stream — WaterFOG — Solid Water Stream.

And Rockwood FOAM Fire Truck Proportioning Systems provide close control of FOAM liquid proportioning *automatically* — another vital step in the efficient use of manpower.

Rockwood Handline, Ground-sweep, Under Truck Nozzles and custom designed specialty parts combine to round out the complete line of FOAM equipment . . . the most advanced, most effective tools for fire protection, regardless of your particular needs. For details, write Rockwood Sprinkler Company, Portable Fire Protection Department, 520 Harlow Street, Worcester 5, Mass. Distributors in all principal cities. Rockwood Sprinkler Company, A Division of The Gamewell Company, A Subsidiary of E.W. Bliss Company. *Rockwood engineers water . . . to cut fire losses.*

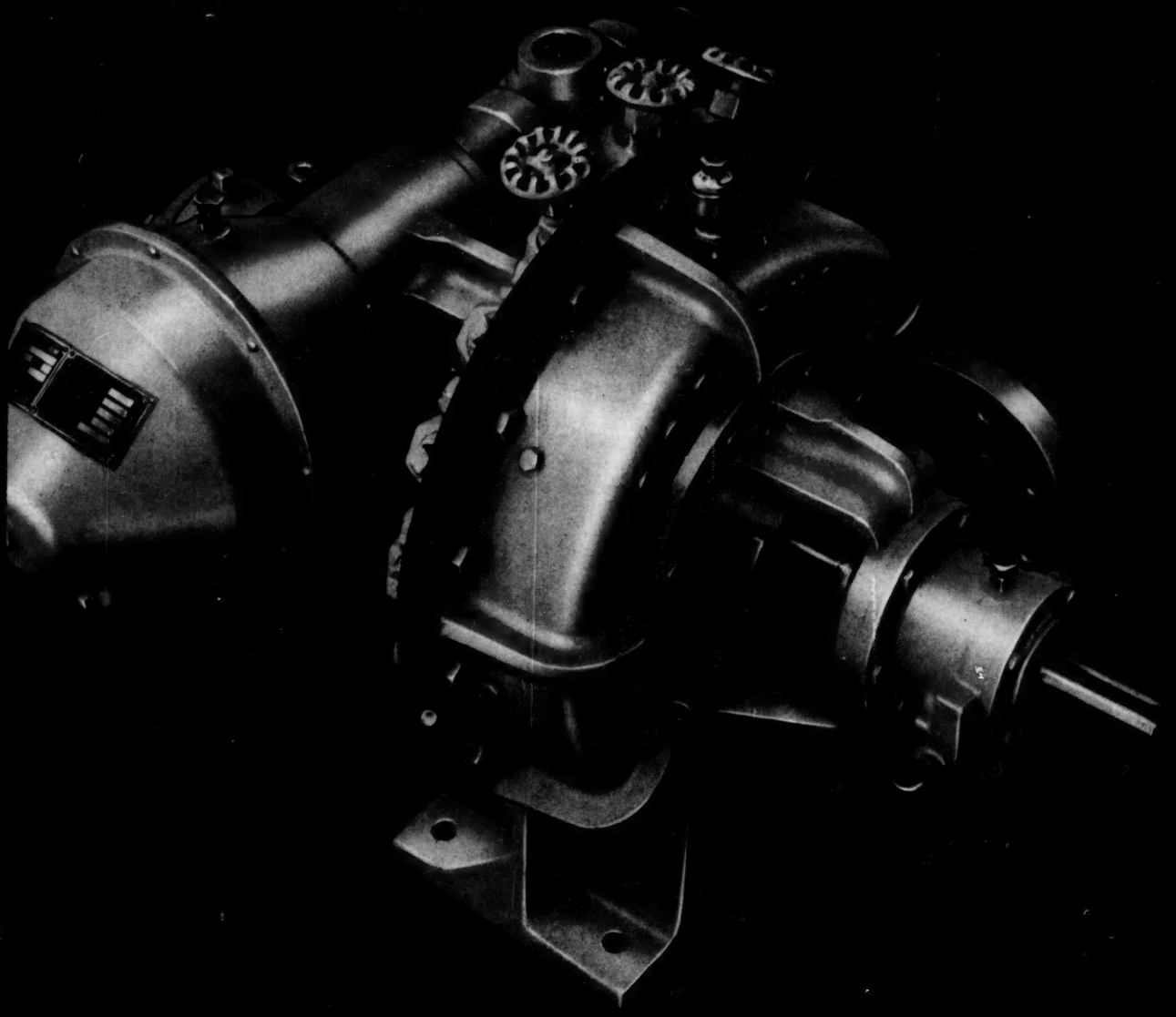




ROCKWOOD

PORTABLE FIRE FIGHTING EQUIPMENT

COPPUS | BLUE RIBBON PRODUCTS



Coppus Horizontal Steam Turbine

NEW RUGGED DESIGN—BLUE RIBBON RELIABILITY!

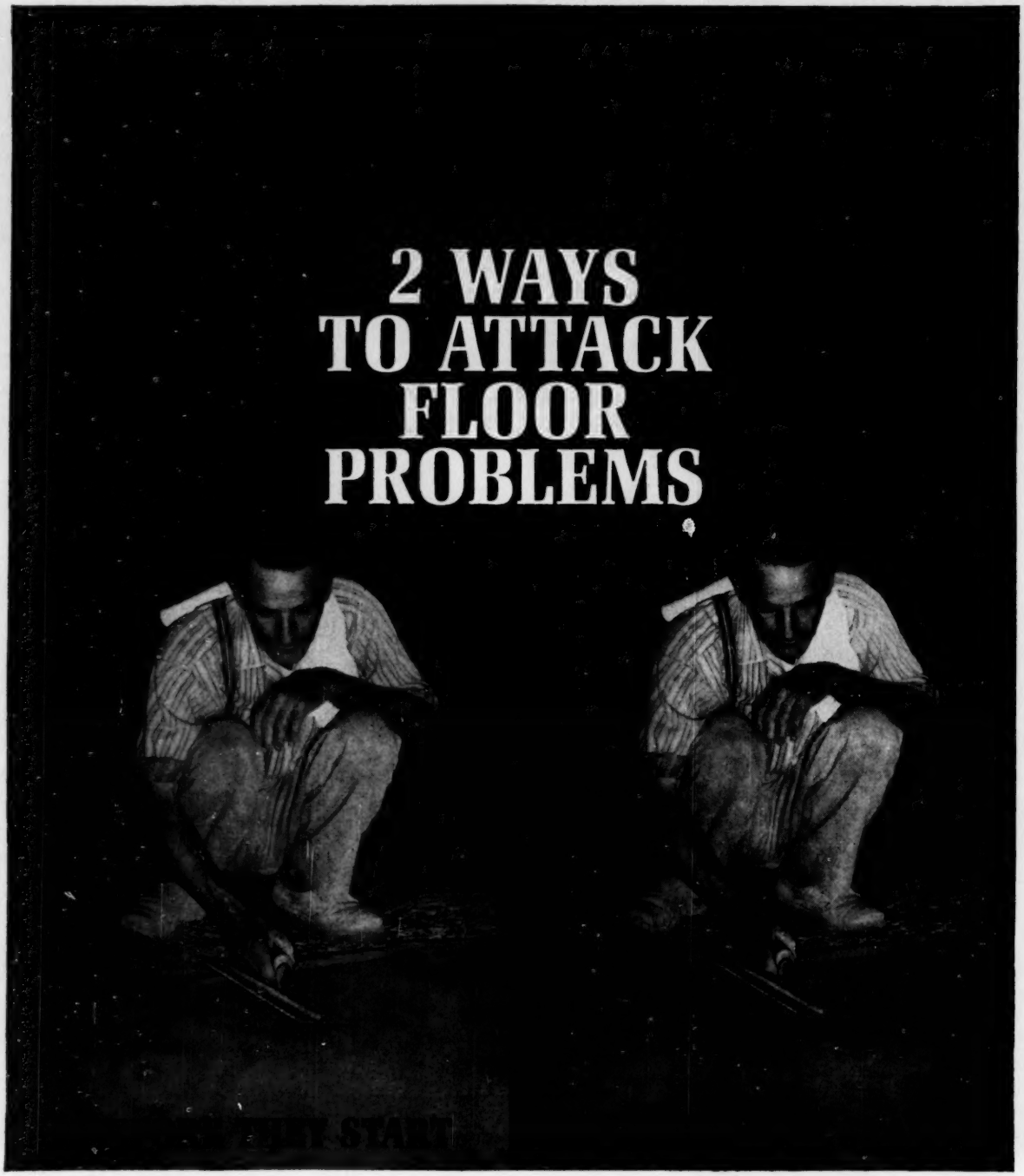
Here's a new dimension in turbine performance! Coppus brings you a new rugged stability of design . . . a new measure of reliability in a complete range of power-packed turbines, from 1 HP to 250 HP — marked with the Blue Ribbon only after each is precision made . . . precision tested. Performance features like these assure you Blue Ribbon Reliability —

A totally enclosed governor . . . totally enclosed, independently operated safety trip . . . easily replaceable packing and bearings . . . multiple steam nozzle control . . . brake rim for added safety . . . wide bucket "L" type wheel (optional) for minimum water rate.

Coppus Turbines are built to customers' specifications, including API and NEMA standards. All Coppus Products carry the same Blue Ribbon assurance of reliable performance. For further facts on turbines, send for new Catalog 200. COPPUS ENGINEERING CORPORATION, 226 Park Avenue, Worcester, Mass. Sales Offices in *Thomas' Register*.

COPPUS
STEAM TURBINES

2 WAYS TO ATTACK FLOOR PROBLEMS



THIOKOL LIQUID POLYMER-BASE MORTARS with epoxies are meeting industry's most serious flooring problems.

IN PLANTS GOING UP—where the manufacturing process is recognized as potentially destructive to conventional materials—liquid polymer-base mortars can be installed originally to avoid frequent, costly maintenance.

IN EXISTING PLANTS—faced heretofore with a continuing cycle of restoration—liquid polymer base mortars have been used for remedial application. These compounds have ended, once and for all, profit-robbing down time, hazards to personnel, unsightliness, and high maintenance outlays.

THIOKOL liquid polymer-base mortar stands up to heavy traffic, abrasion, chemical attack like no other flooring compound. It can be applied over existing surfaces regardless of their composition, and is ready for traffic in less than a day. For complete data, send for Brochure FC-100.

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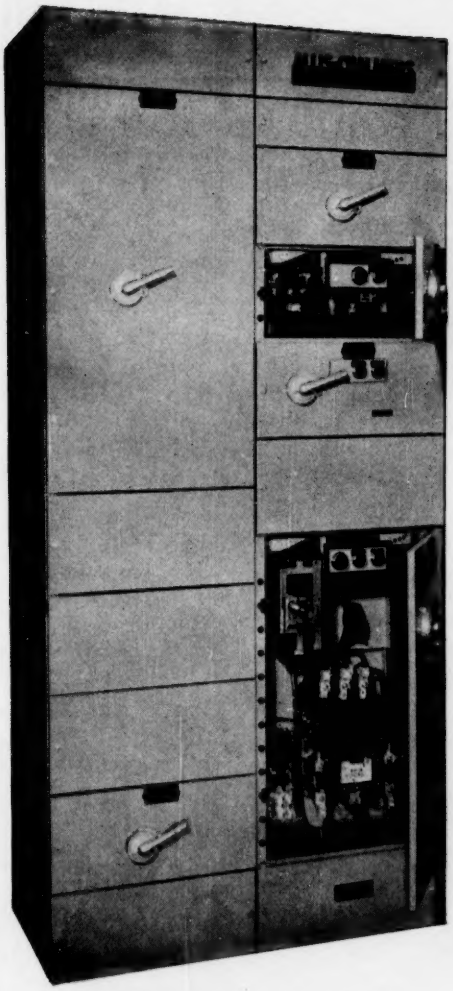
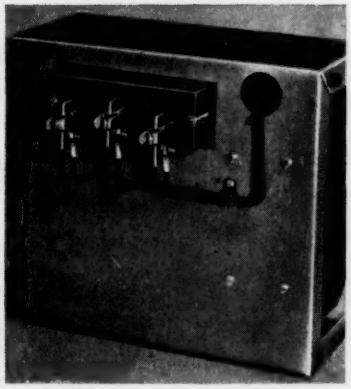
ALLIS-CHALMERS

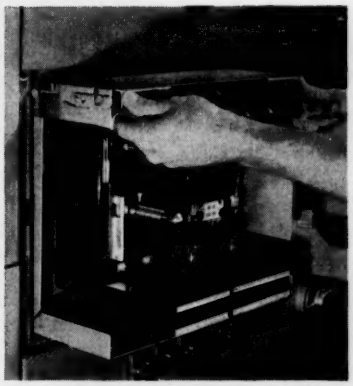


1. Centralized control saves space, cuts installation and engineering costs.

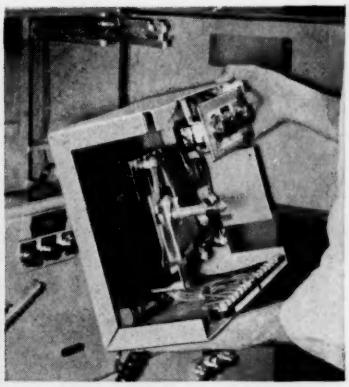
2. Exclusive plug-in terminal blocks permit removal of units without tools. Fully accessible location at front of units simplifies your wiring.



3. Extra heavy plug-in stabs and positive alignment provided by TRACK-GUIDE drawout mechanism assure trouble-free electrical connection.



4. With TRACK-GUIDE mechanism, units can be easily and safely de-energized and locked out, or withdrawn from enclosure for inspection and maintenance.



5. Units can be tilted up for inspection of stabs without removing from TRACK-GUIDE mechanism, or fully removed for bench maintenance or interchange.

...six reasons why Allis-Chalmers new motor control center design is

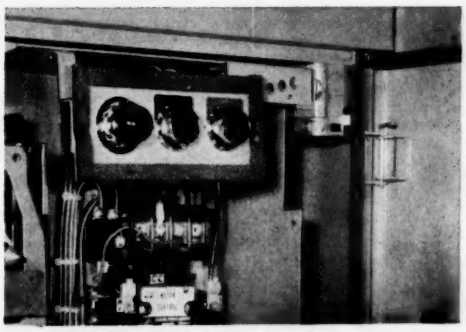
the center of satisfaction

Satisfaction? It comes with every one of the new (yet fully proven) low-voltage control centers from A-C. Their clean lean design saves valuable space. Exclusive plug-in terminal blocks cut installation time . . . speed inspection and removal. *Track-Guide* drawout mechanism lowers maintenance costs. Control units can be drawn out, tilted up, or completely removed without tools.

Safety features of these new control centers provide *sure* protection to personnel. Units can be quickly de-energized for maintenance or inspection work. Units cannot accidentally fall out of *Track-Guide* mechanism during inspection or maintenance.

Reliability . . . versatility . . . economy . . . strength . . . safety. You name the feature — A-C motor control centers have it. *Ask your A-C representative or distributor for all the facts. Or write* **Allis-Chalmers,** *Industrial Equipment Division, Milwaukee 1, Wis.*

Track-Guide is an Allis-Chalmers trademark. A-1486



6. Mounting of pilot lights and pushbuttons on the removable control units eliminates failures common with hinged wiring.

PROTECTOR OF YOUR PROFITS!

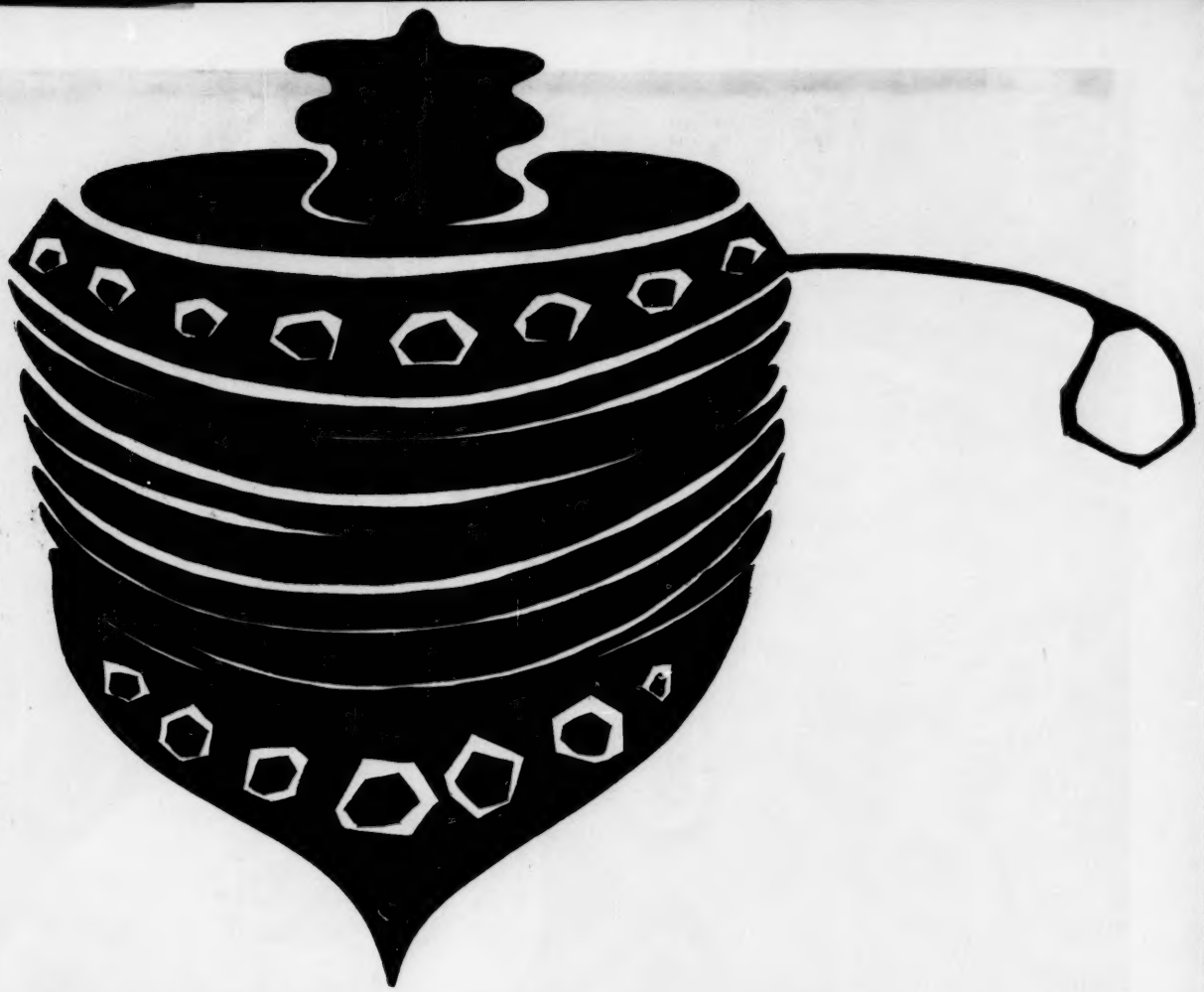
Dust is a destroyer. It corrodes. It abrades. It ups down-time. That's why you need protection from this menace. Pangborn Dust Control Equipment provides you with this protection.

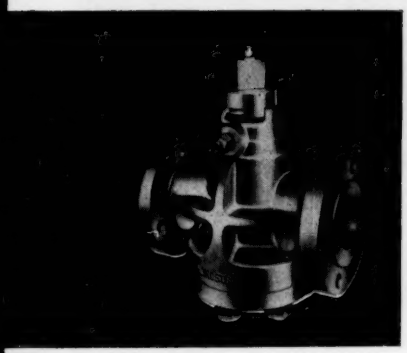
Eliminating costly dust damage is just one of the many money-saving functions of Pangborn Dust Control Equipment. It also improves plant housekeeping. It protects men as well as equipment. It salvages usable dust. And it can improve your relations with your community.

Pangborn has the right dust collector to fit every requirement. Cloth Bag, Tube, Screen, Self-Cleaning and Unit Type Dry Collectors, also Wet Collectors in all sizes. For more facts, write:

Pangborn Corporation, 2600 Pangborn Blvd., Hagerstown, Md.; Pangborn Canada,Ltd., 47 Shaft Rd., Toronto (Rexdale), Canada —Manufacturers of Dust Control, Blast Cleaning, Vibratory Finishing Equipment; Rotoblast® Steel Shot and Grit®.

Pangborn
OF HAGERSTOWN





easy to turn: The longest time in the world can be the time it takes to close a valve . . . when you have to close it in a hurry. The sure, easy quarter turn closure of Rockwell-Nordstrom valves saves seconds, even minutes. And you'll save hours of maintenance time on seat replacement with the Rockwell-Nordstrom's sealant system, which replaces the valve's seat from outside. The longer life of these valves—six, eight, even ten times ordinary types—saves days of replacement labor. Add up these times, multiply by the valves in your plant, then again by your labor rate: the result may amaze you. We'll be happy to send you complete information.

ROCKWELL-Nordstrom VALVES
another fine product by
ROCKWELL

Write to:
Rockwell Manufacturing Company
105F N. Lexington Ave.,
Pittsburgh 8, Pa.
Canadian Valve Licensee:
Peacock Brothers, Ltd.
Box 1040, Montreal, Quebec
Rockwell International, S.A.
81 Rue de la Servette
Geneva, Switzerland

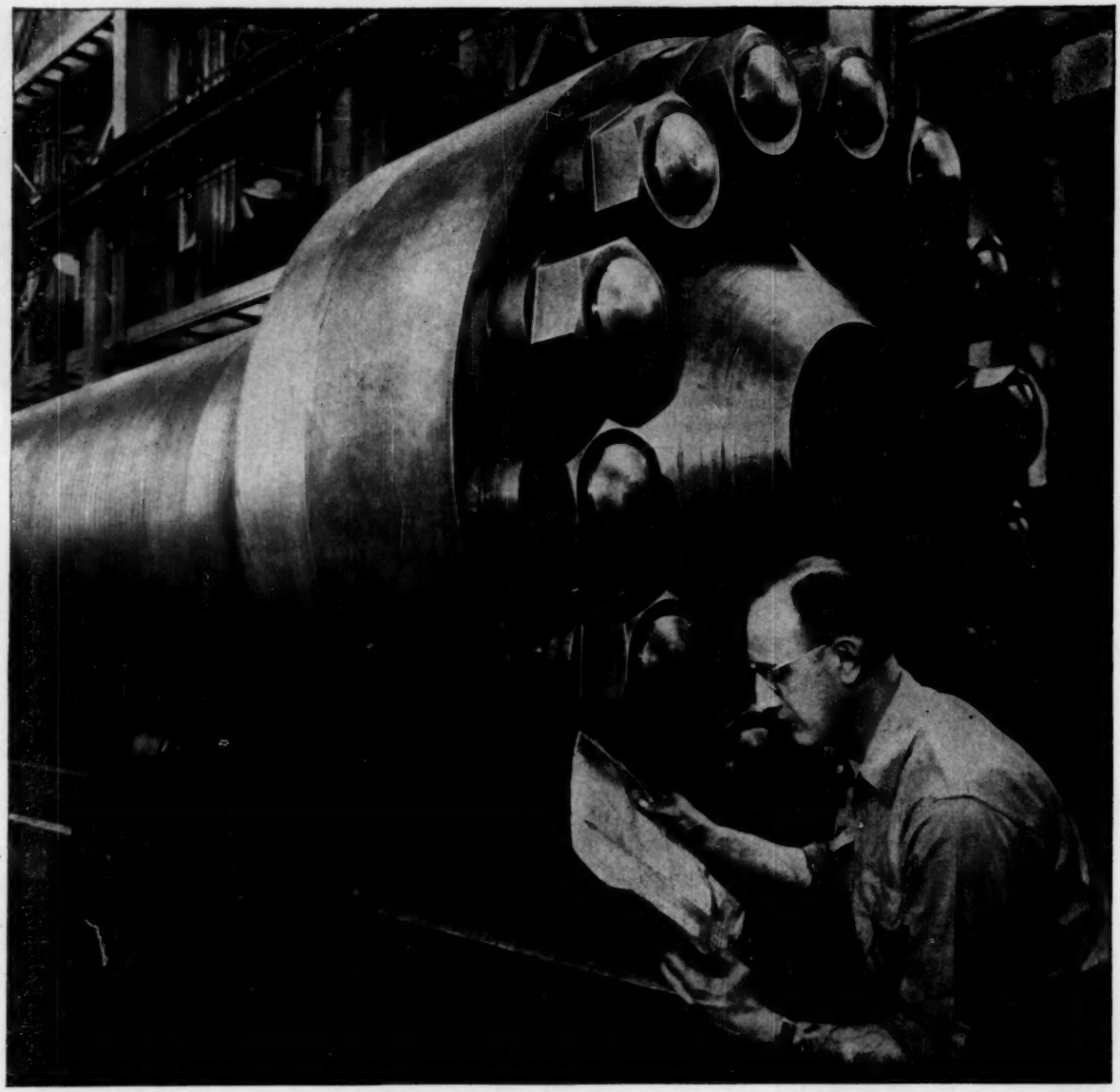
Please send me Bulletin V-618.

Name _____

Company _____

Street _____

City _____ Zone ____ State ____



Strong, Seamless Walls 7½ in. Thick

This forged Bethlehem converter, built for use in the making of ammonia, weighs 48 tons. Much of the weight is in the rugged seamless walls, which are solid steel, 7½ in. thick. Those walls are built to contain high pressures, and they will do the job.

Another interesting feature is the circle of huge nuts that hold the vessel's head to the body. Each of them weighs 77 lb and has a diameter of 10 in. There are 14 nuts and matching studs — convincing evidence of the pressures to be handled.

This could be called a typical Bethlehem vessel of medium weight. Our shops are equipped to build both larger and smaller models of autoclaves, reactors, filters, converters, separators, and high-pressure accumulators. Whatever your needs, Bethlehem can meet them—at competitive prices. Deliveries are prompt. Write for details.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

Export Sales: Bethlehem Steel Export Corporation

Steel

For strength
. . . economy
. . . versatility

BETHLEHEM STEEL

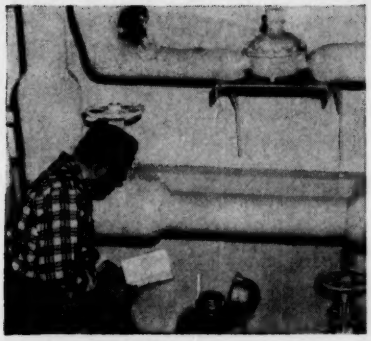
BETHLEHEM STEEL

neptune

An advertisement written to help you

Measurement/Control News

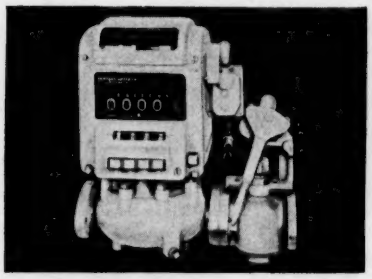
prepared by Neptune Meter Company



Ansco Finds Savings With 100 Meters

BINGHAMTON, N.Y.—Making fine films requires millions of gallons of water daily . . . much of it expensively treated. Using over 100 water meters, Ansco Manufacturing Co. has cut costs to the bone by finding ways to re-use water an average of *2½ to 3 times.*

In one case, the same well water passes through *seven* uses: air conditioning, spray washing, chemical dehumidifier, heat exchanger, ammonia condenser, fire protection reservoir, and finally, roof cooling. The meters help compute heat exchange values, blending proportions, chemical treatment, etc., and each department is charged for what it uses.



Switch on Meter Automatically Controls Pumps

Highly educated meter incorporates an explosion-proof switch which trips when any preset quantity of liquid has passed through. Can be used to actuate solenoids, start and stop pumps, agitators, etc.

METER CALIBRATION is quick and easy with Neptune "400" registers. Remove register cover, lift shifter plate, turn to desired setting, drop into place. Once set, it's gear-locked, can't drift or shift. Neptune recommends regular testing, will show you how.

Automatic Meters Improve Viscosity Control in Latex Paints

Two Neptune Auto-Stops replace gauge sticks in measuring Polyvinyl acetate and water

KANSAS CITY, MO.—To save time lost making adjustments in viscosity of latex base paints, Seidlitz Paint & Varnish Co. now uses accurate positive displacement meters on both polyvinyl acetate latex and water.

Batches formerly were measured by gauge stick or tank marks. Many required final adjustments to meet rigid viscosity standards.

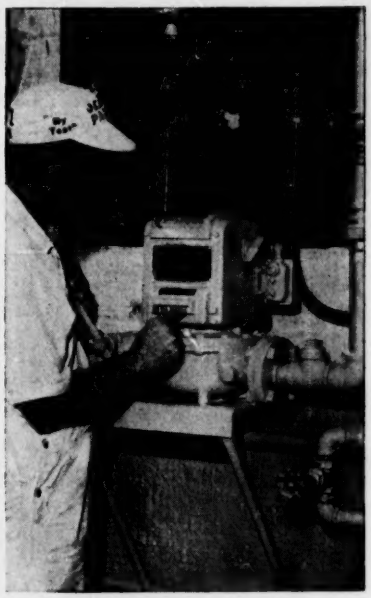
Push-buttons set quantity

Drying agents, pigments and bodying agents are first mixed in 54-inch Cowles dissolver with a preset quantity of water metered through 1-in. Neptune Auto-Stop meter. Operator pushes buttons to set meter, opens valve, then spends time on dry ingredients while meter is operating. Meter shuts off automatically.

This grinding mix, followed by a quantity of wash water to clear out the mixer, then goes to a finishing tank downstairs, where latex and thinning water are metered in. Latex meter is 1½ in. Auto-Stop, with a double-trip valve which prevents hydraulic shock in lines by providing 2-stage closing.

Auto-Switch turns off pump

An explosion-proof switch is featured with the metering equipment to automatically control the latex pump located in the basement. The registers

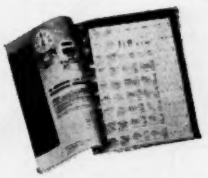


are equipped with cumulative totalizer and large numeral wheels which are reset with each batch.

The meters have been in use for 18 months with a fine record for accuracy, states Vice President R. W. Brown. Meters make savings like this with hundreds of industrial liquids. The Neptune sales representative near you can offer helpful suggestions regarding meter size and type.

HELPFUL METERING DATA AVAILABLE

28-pg. technical bulletin lists liquids, helps pick proper sizes and features of meters 2 to 2000 gpm.



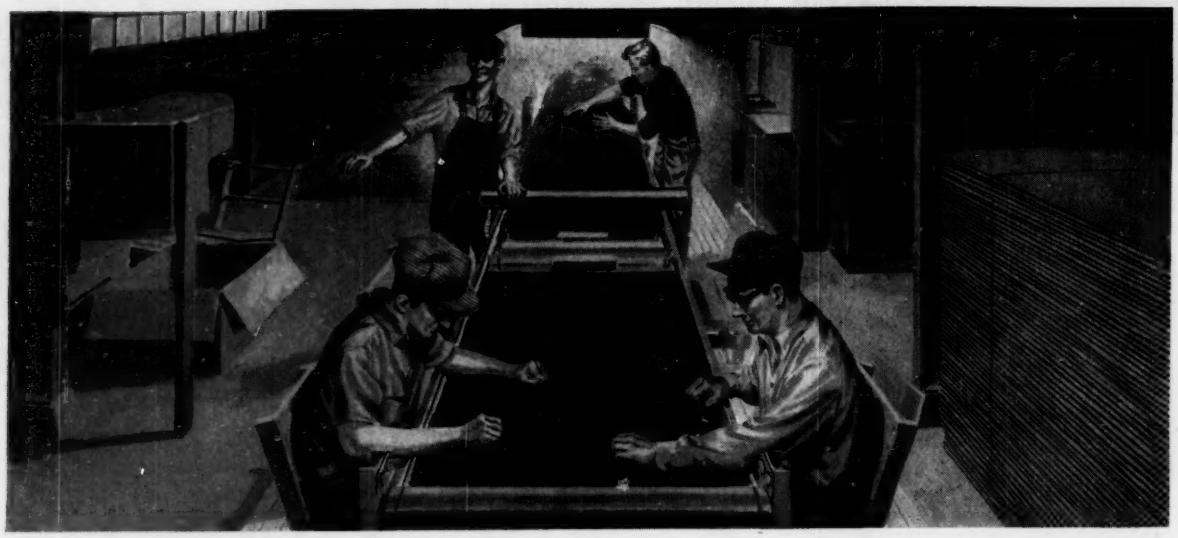
NEPTUNE METER COMPANY · Liquid Meter Division
47-25 34th St., Long Island City 1, N.Y.

Please send me helpful Meter Bulletin 566N

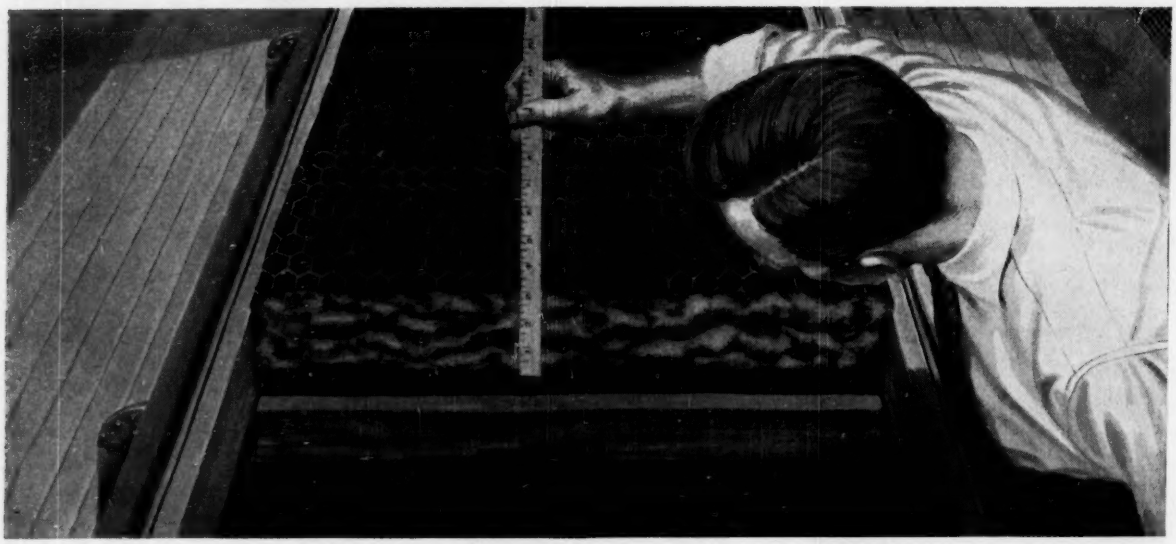
NAME_____ TITLE_____

COMPANY_____

ADDRESS_____ CITY & STATE_____



FACTORY FABRICATED TO RIGID SPECIFICATIONS!



Don't risk efficiency with careless, made-on-the-job blankets.

- Copper bearing steel laths, bound by uniformly spaced soft-drawn galvanized tie wires, keep blankets firm but flexible.
- Eagle-Picher mineral wool evenly dispersed over entire insulating area of each blanket.
- Completely free of large voids usually found in field-made blankets where insulation is haphazardly packed in place.
- Smooth edges butted tightly together eliminate cracks and loose joints.
- Quickly applied to flat or slightly curved surfaces of any large equipment—or cut to fit irregular areas.
- Maximum thermal efficiency at temperatures as high as 1200 F.

Eagle-Picher produces a complete line of industrial insulations for all temperatures from below Zero to over 2000 F.

EAGLE-PICHER BLANKET INSULATION

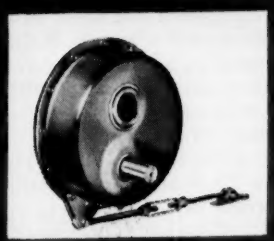
This Mineral Wool Insulation conforms to COMMERCIAL STANDARD CS-117-49 as issued by U.S. DEPARTMENT of COMMERCE.

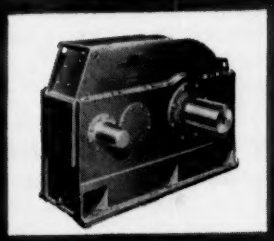
EAGLE-PICHER / Manufacturer's Manufacturer

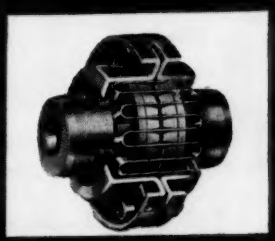
Since 1843 / The Eagle-Picher Company
Dept. CE-612
Cincinnati 1, Ohio

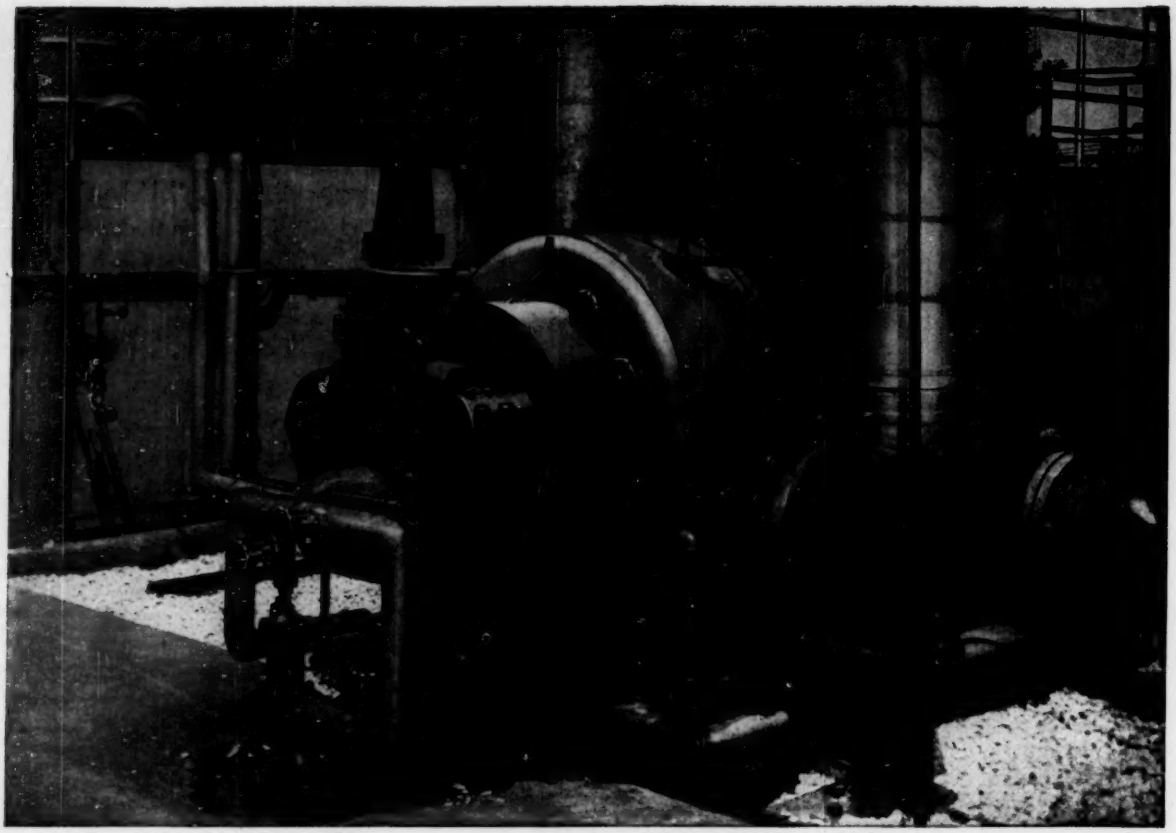
EAGLE EP PICHER

FALK



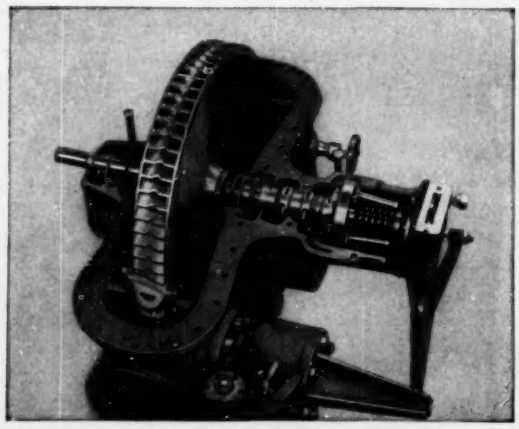






TERRY SOLID-WHEEL TURBINES

used exclusively at Baton Rouge plant of W.R.Grace & Co.



The upper photograph shows one of the 17 Terry turbines installed at the Baton Rouge, La., GREX high-density polyethylene plant of W. R. Grace & Co. Above, a typical Terry solid-wheel turbine with cover removed to show the wheel construction.

In purchasing equipment for their new 50,000,000-pound high-density polyethylene plant, W. R. Grace & Co. standardized, wherever possible, on a single source of supply for each type of equipment used. Consistent with this policy, Terry steam turbines were used exclusively throughout the utility and process sections of the plant.

A total of 17 turbines were placed in service for driving pumps and fans. These are all of the solid-wheel type, ranging in capacity from 50 to 240 HP.

Terry solid-wheel turbines are known for their long life and sure dependability under the most-trying operating conditions. They feature a single-piece wheel which is virtually indestructible.

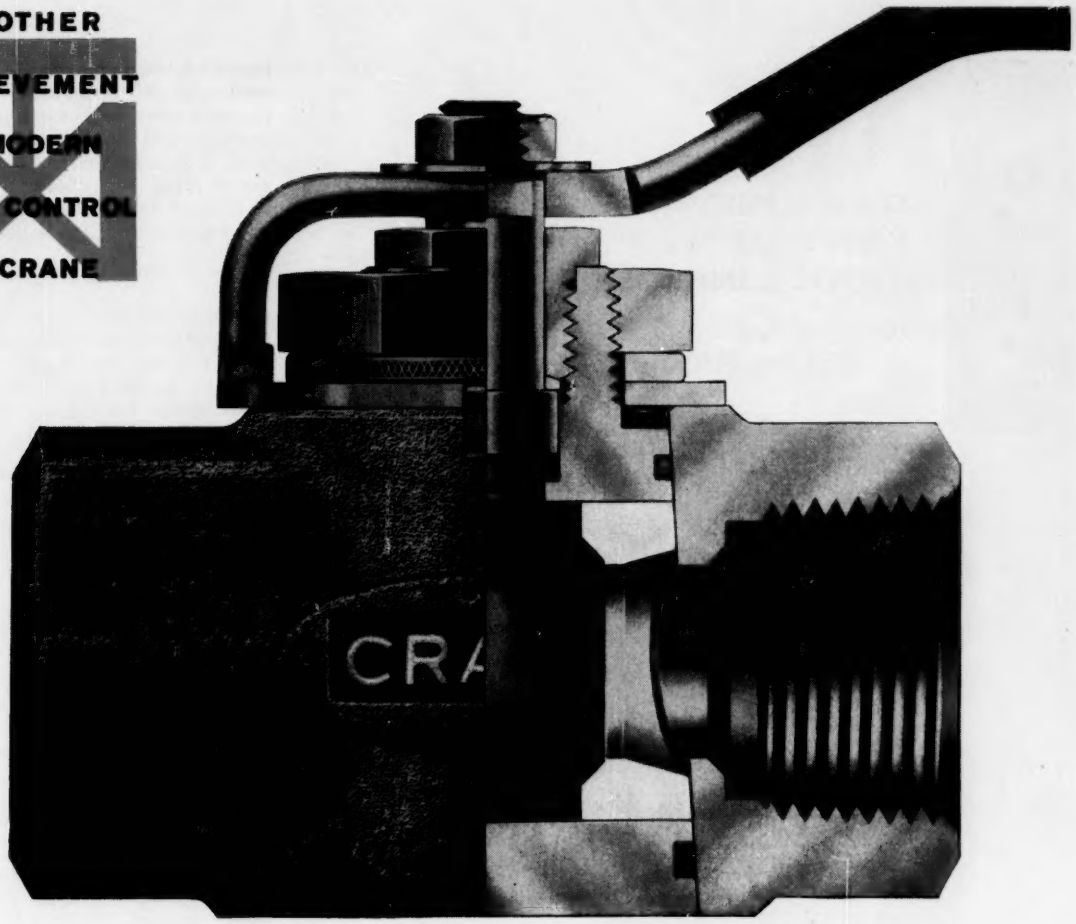
Send for details of these trouble-free turbines. Ask for a copy of bulletin S-116.

THE TERRY STEAM TURBINE COMPANY
TERRY SQUARE, HARTFORD 1, CONN.

TERRY

TT-1214

ANOTHER ACHIEVEMENT IN MODERN FLOW CONTROL BY CRANE



this ball beats all!

CRANE BALL VALVES are engineered for superior flow control and minimum-maintenance operation. The secret of this valve's all-around outstanding performance is its beautifully simple, Crane-designed tapered cartridge containing all the working parts. While the valve body remains in line, acting as a pipe connection, the entire cartridge may be removed from the bottom, quickly and easily, for fast exchange or simple, low-cost maintenance.

Precision pre-loaded Teflon* seats assure bottle-tight closing in either direction with a quick, easy quarter turn of the bright, Crane orange insulated handle. The self-aligning, precision machined ball is polished and chrome-plated to reduce friction and wear on the self-cleaning seats. All steel parts are plated for corrosion resistance. Crane Ball Valves handle fluid, gas and air services from vacuum to 800 psi and temperatures from –40 to 400F. Available now from your Crane Distributor for prompt delivery–sizes from ¼" to 2", screwed ends, in bronze, carbon steel, and Type 316 Stainless.

*Registered DuPont trademark.

at the heart of home and industry

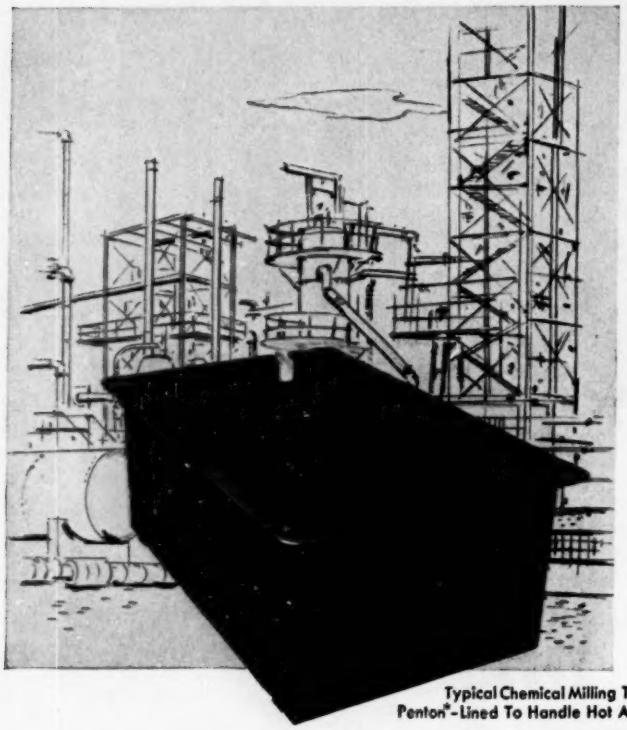
CRANE

valves
piping • electronic controls
plumbing • heating
air conditioning

Contact your Crane Distributor or write: Crane Co., Industrial Products Group, 4100 S. Kedzie Ave., Chicago 32, Ill., for illustrated brochure ADB 1001 with complete information on Crane Ball Valves. In Canada: Crane, Ltd., 1170 Beaver Hall Square, Montreal.

GAR-LINE PENTON TANK LININGS

for Corrosion Resistant Service



Typical Chemical Milling Tank Penton*-Lined To Handle Hot Acids

New GAR-LINE Penton Tank Linings offer economical, high-temperature protection against corrosion. Where only more expensive materials were previously used, GAR-LINE Penton Tank Linings are proving their ability to perform as well as—and better—in many corrosive exposures at high temperatures.

Unique Properties. Mechanically, GAR-LINE Penton Tank Linings exhibit excellent tensile strength at high temperatures, good dimensional stability and low water absorption . . . Chemically, they resist all inorganic acids except fuming nitric and fuming sulfuric.

Applied by these carefully selected and authorized applicators:

ABRASION & CORROSION ENGRS.
1205 N. McMasters Street
Amarillo, Texas

AUTOMOTIVE RUBBER CO., INC.
12580 Beech Road
Detroit 39, Michigan

BARTHEL CHEMICAL CONST. CO., INC.
P.O. Box 1025
Tacoma 1, Washington

BELKE MFG. CO., INC.
947 N. Cicero Avenue
Chicago 51, Illinois

BITTNER INDUSTRIES, INC.
91 Diaz Street
P.O. Box 10265
Prichard, Alabama

BUCKLEY IRON WORKS
21 Christopher Street
Dorchester, Massachusetts

BUFFALO LINING & FABRICATING CORP.
73 Gillette Avenue
Buffalo 14, New York

CHEMICAL PROOF OF SEATTLE
625 Alaska Avenue
Seattle, Washington

CORROSION TREATMENT CORP.
P.O. Box 125
Byesville, Ohio

ELCHEM ENGRG. & MFG. LTD.
P.O. Box 249
Burlington, Ontario, Canada

ELECTRO CHEMICAL ENGRG. & MFG. CO.
750 Broad Street
Emmaus, Pennsylvania

FLORIDA CORROSION CONTROL
2939 W. Beaver Street
P.O. Box 10082
Jacksonville 7, Fla.

THE FORTUNE COMPANY
1100 W. 37th St. North
Wichita 4, Kansas

GALIGHER COMPANY
545 West 8th—South
Salt Lake City, Utah

GOLDEN PLASTICS CORP.
333 East 8th St.
Oakland 6, California

GOODALL RUBBER COMPANY
2050 N. Hawthorne Avenue
Melrose Park, Illinois

HANSZEN PLASTICS COMPANY
835 S. Good-Latimer Expressway
Dallas, Texas

HEIL PROCESS EQUIPMENT CORP.
12901 Elmwood Avenue
Cleveland 11, Ohio

HUNTINGTON RUBBER MILLS of PORT COQUITLAM
B.C., Canada

INNER-TANK LINING CORP.
4777 Eastern Avenue
Cincinnati 26, Ohio

MAURICE A. KNIGHT
Kelly Avenue
Akron 9, Ohio

MERCER RUBBER CORPORATION
Highway 46, Cor. Huyler
Little Ferry, New Jersey

METALWELD, INC.
Scotts Lane & Abbottsford Rd.
Philadelphia 29, Pennsylvania

PARKER BROTHERS, INC.
7044 Bandini Blvd.
Los Angeles 22, California

PLASTICS APPLICATORS, INC.
7020 Katy Rd.
P.O. Box 7631
Houston 7, Texas

PROTECTIVE COATINGS
1602 Birchwood Avenue
Ft. Wayne, Indiana

RUBBER ENGINEERING & MFG. CO.
P.O. Box 2335
Salt Lake City 10, Utah

RUBBER MILLERS, INC.
707 S. Caton Avenue
Baltimore, Maryland

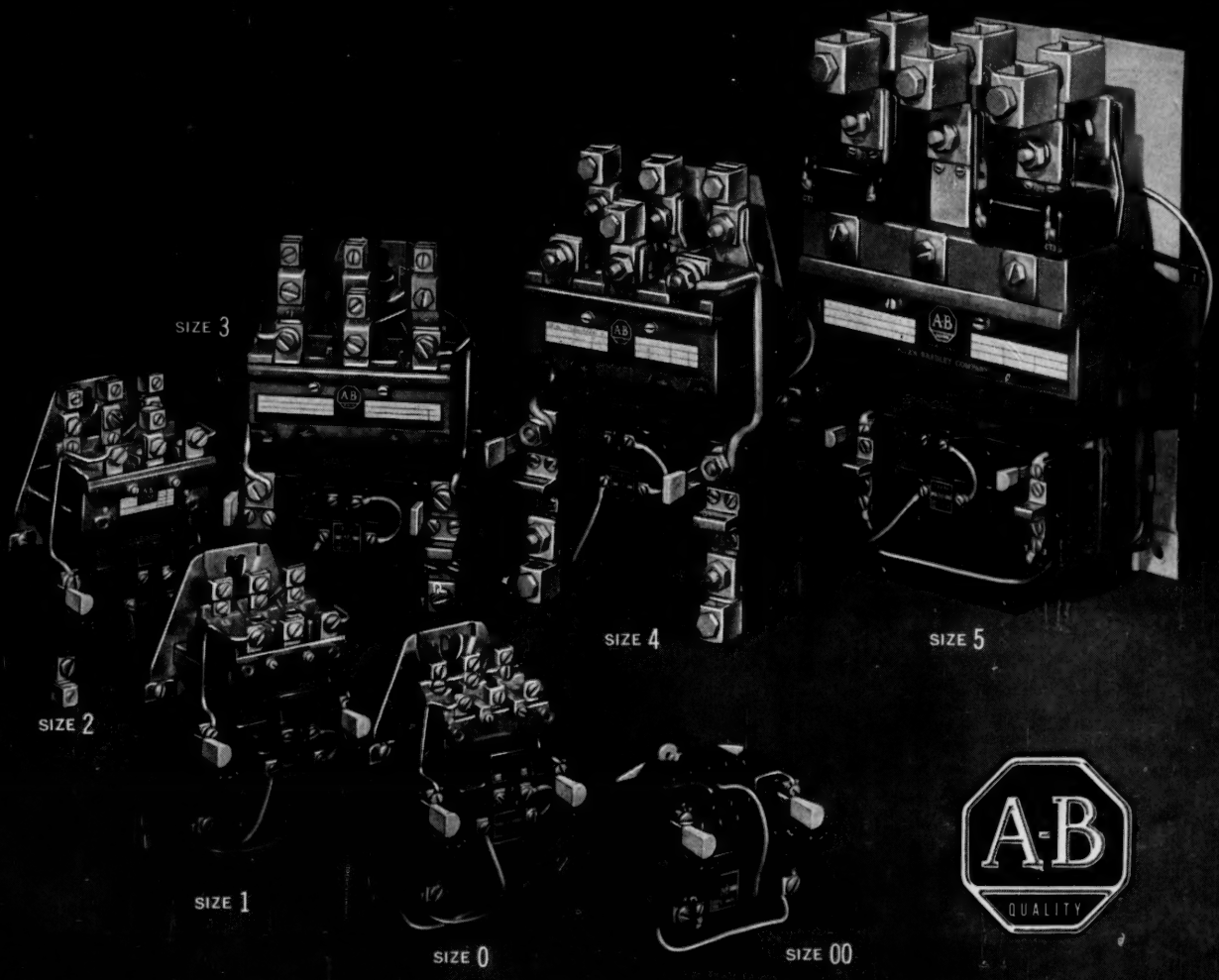
ST. LOUIS METALLIZING CO.
625 S. Sarah Street
St. Louis 10, Missouri

STEBBINS ENGRG. & MFG. COMPANY
Watertown, New York

GARLOCK

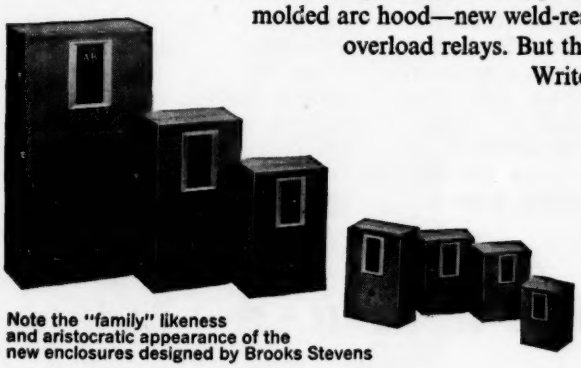
For more information, contact the applicator nearest to you. Or, write for data on Penton; information also available on Teflon Anti-Stick and Teflon† Tank Linings. Special Products Dept., Garlock Inc., P.O. Box 612, Camden 1, New Jersey.

*Registered Trademark, Hercules Powder Company
†Registered Trademark, The DuPont Company



the greatest advance in motor control in 30 years

From their amazing compactness to their almost unbelievable operating life—measured in *millions* of operations—this entire family of Bulletin 709 solenoid starters is *new in every detail.* They feature a new, patented, high-efficiency magnet—new molded coil—new hot molded arc hood—new weld-resistant contacts—and new truly *trip-free* and *tamperproof* overload relays. But these new starters use the old Bulletin 709 heater elements. Write today for all the details on this really amazing new line of Allen-Bradley Bulletin 709 motor starters.



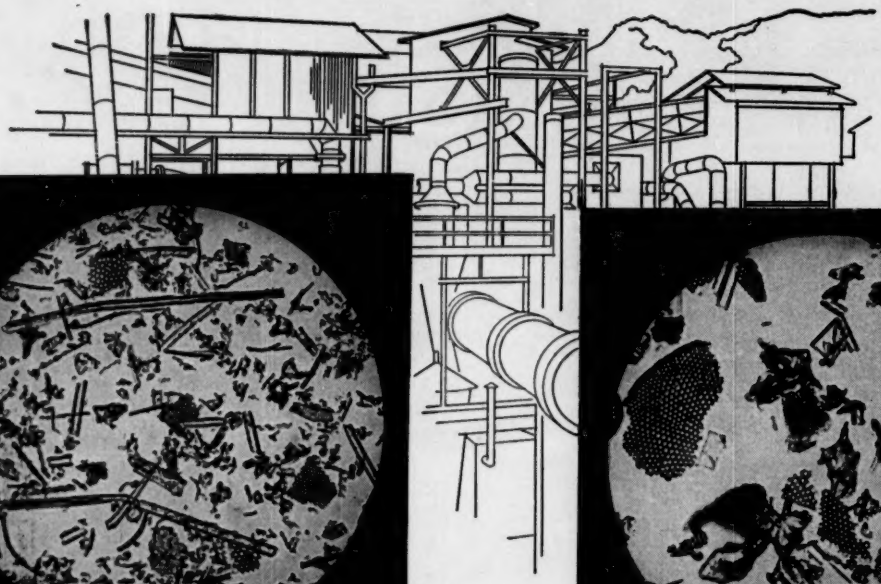
Note the "family" likeness and aristocratic appearance of the new enclosures designed by Brooks Stevens

ALLEN-BRADLEY

Member of NEMA

Quality Motor Control

Allen-Bradley Co., 1337 S. First St., Milwaukee 4, Wis.



Milling and calcining equipment used for all Celite grades.

For high-clarity filtration of most liquids—use this specially milled diatomite, Hyflo Super Cel.

For filtration of larger suspended particles—Celite 545 combines maximum clarity plus faster flow rates.

In diatomites, Johns-Manville precision processing works for you

Constant uniformity in every grade of Celite assures consistent results, less down-time

For mineral filler use—Super Floss grade is made up of carefully sized fines air-floated off in the bag house.

Typical J-M bag house equipment.

AS THE MICROSCOPE SHOWS, each grade of Celite* diatomite has its own distinctive particle size distribution. Yet no matter where or when purchased, each remains uniform from bag to bag—your assurance of top production results with minimum down-time.

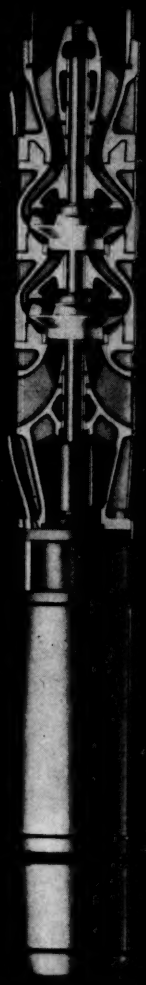
Three examples of flux-calcined Celites are shown here. Hyflo® Super Cel is widely used for filtration in many industries. It has just the right combination of coarse and fine particles to assure optimum clarity and flow rates. Celite 545, with a higher percentage of coarse particles, is used to achieve maximum clarity and faster flow rates with liquids that have larger suspended particles.

Super Floss, one of several bag house grades, has fine particle size distribution. A white powder, it is processed within very narrow tolerances (less than 1% retained on 325 mesh). It is a popular filler in fine products such as silver polishes.

Johns-Manville can precision-produce so many different grades of Celite because it mines the material from the world's largest and purest commercially available deposit. For assistance with specific filtration or mineral filler problems, talk to a nearby Celite engineer. Or write direct to Johns-Manville, Box 14, New York 16, N. Y. In Canada, Port Credit, Ontario.

*Celite is Johns-Manville's registered trade mark for its diatomaceous silica products.

JOHNS-MANVILLE



Regular Submersible

SUBMERSIBLE PUMPS

deliver water

economically

consistently

silently

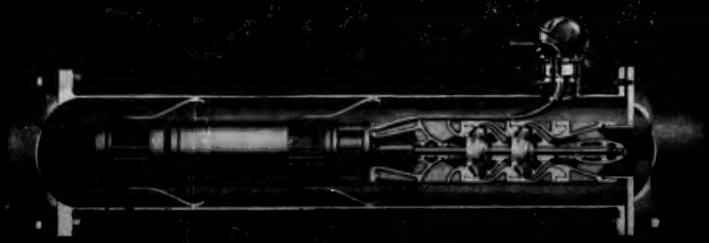
efficiently

The Layne Submersible Pump installation gives you noise free operation because the pump and motor are completely submerged. The Layne Submersible is adaptable to all wells; requires a minimum of space since no pump house is required; eliminates possibility of water contamination; and eliminates the opportunity for vandalism or other accidental mishap or damage.

Layne Submersible Pumps are available for wells as small as 6 inches and in capacities from 30 GPM up. For additional information write for free bulletin number 202.

The Layne In-Line Submersible pump provides the answer to many problems in booster pump applications. The pump operates as an integral part of the line and is designed for use by municipalities, industry, such as petroleum and chemical plants and by agriculture. Advantages include: simple installation, no additional space required, continuous service even under flood conditions, and no possibility of surface water contamination.

Layne In-Line pumps are made as small as 4 inch bowls on a 4 inch motor for use in a 6 inch pipe to deliver 30 GPM. Larger sizes are available as required. For additional information write for free bulletin number 203.



In-Line Submersible

Layne SINCE 1882 — COMPLETE WATER SERVICE

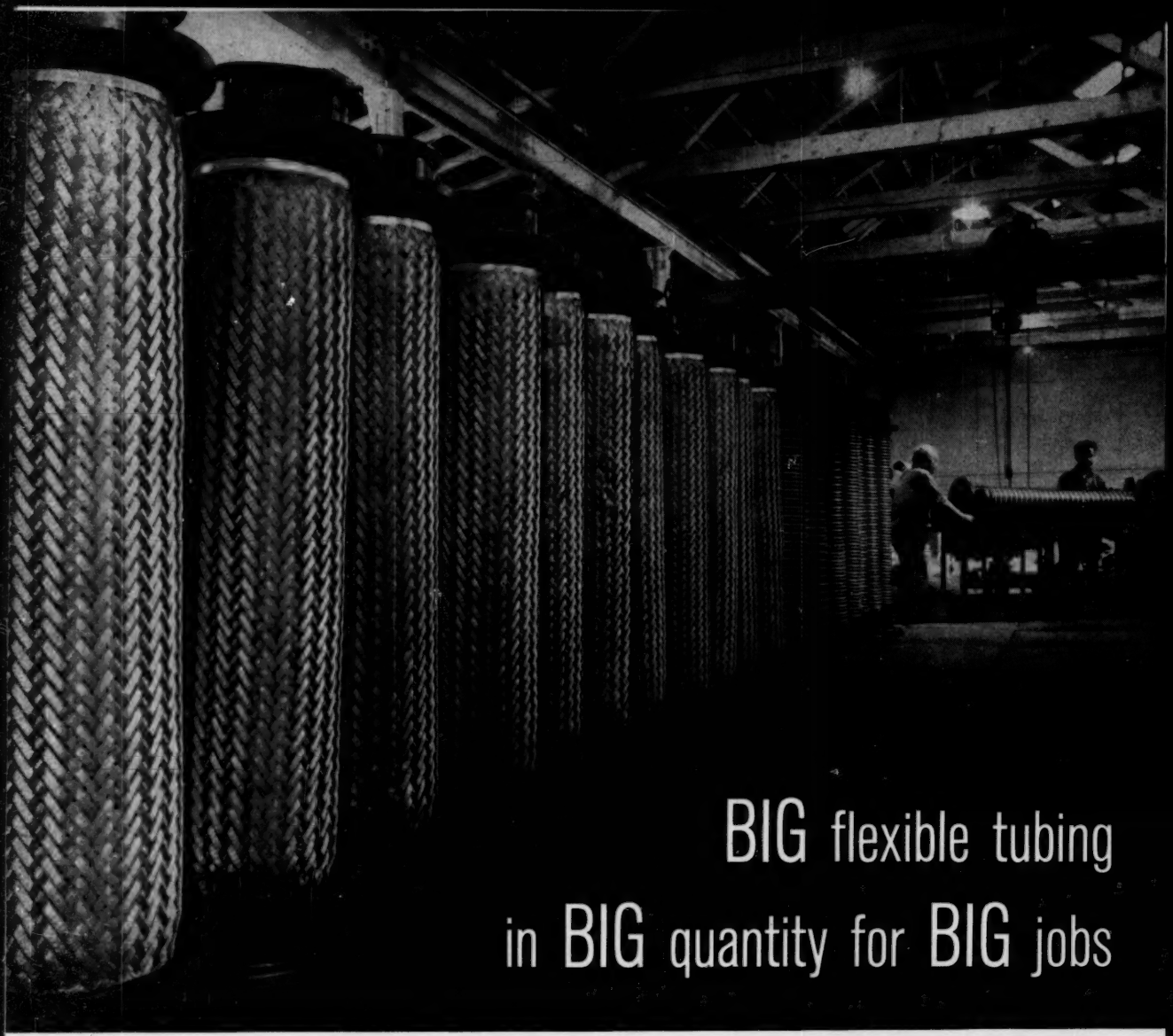
LAYNE & BOWLER, INC., MEMPHIS

General Offices and Factory, Memphis 8, Tenn.

LAYNE ASSOCIATE COMPANIES THROUGHOUT THE WORLD

Sales Representatives in Major Cities

Find LAYNE Fast in the Yellow Pages under pumps



BIG flexible tubing in BIG quantity for BIG jobs

Whatever your flexible metal tubing problem, Anaconda's broad design and manufacturing capability can make your job easier

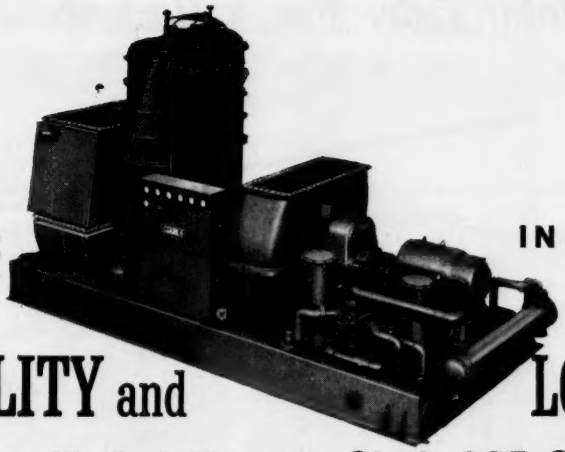
The big corrugated stainless steel tubing assemblies shown above were designed and manufactured by Anaconda Metal Hose for water lines in the missile program. Construction of these 12″ I.D. lines is corrugated stainless steel flexible tubing, reinforced with stainless steel wire braiding; end fittings are floating flanges. This type of tubing can also be produced in other metals as Bronze, Steel, in standard ID's through 16″ and standard lengths of 20 feet.

Small flexible tubing for small tough jobs, too. At the other end of the scale are tiny ⅛″ Vibration Eliminators. And in between, the variety of flexible hose assemblies – in size, material, and design – is almost infinite.

Sales Engineering Consulting Services that follow through from original design to finished product. Simply let us know your needs, with conditions, dimensions, and such sketches and drawings as might be necessary to give us an understanding of your problems. We will work out design problems with your engineers and draftsmen. We will manufacture the flexible connectors. And we will make specialists available for immediate service calls on equipment or field installations. These services are available through our representatives in leading cities–see listing "Hose-Metal" in the Yellow Pages. Or write: Anaconda Metal Hose, Box 791, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

60127

ANACONDA®
Metal Hose



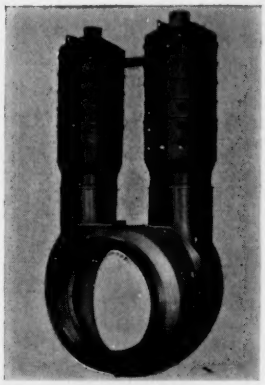
Clark Model 305-S, single shaft gas turbine rated at 9000 hp.

IN GAS TURBINES YOU LOOK FOR

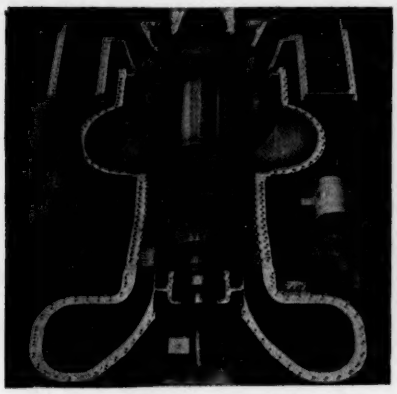
RELIABILITY and LOW FIRST COST

Here's why you'll find them in Clark 305 Series Gas Turbines

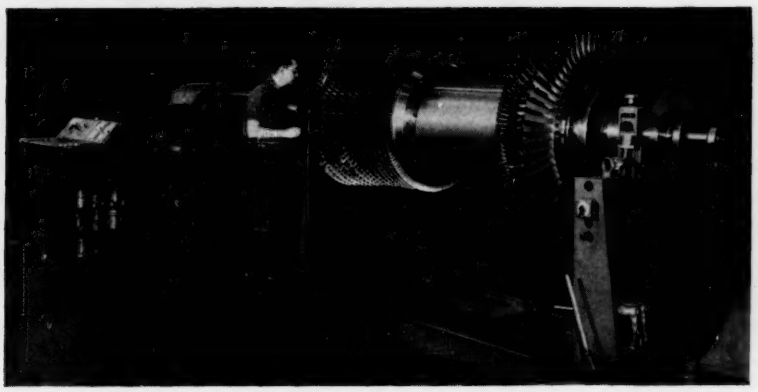
- **Heavy Duty Industrial Design**—Simple, open cycle machines, built for continuous, full load operation... ideal drivers for compressors, generators and pumps.
- **Single Shaft Construction**—Provides high rotating inertia and minimum speed variations under transient load conditions. Two-Shaft units available for applications requiring wider operating flexibility.
- **Design Simplicity**—Integral compressor-turbine rotor is supported by two readily accessible journal bearings. Entire unit including combustion system is contained in common casing structure.
- **1400°F Operating Temperatures**—Insure long life of hot parts plus substantial margin of safety.
- **Air Cooled**—Pressurized air cools high temperature components... air envelopes minimize heat loss and operating temperatures wherever possible.
- **Vertical Combustion Chamber**—Prevents direct flame impingement on turbine blading... assures more uniform heat distribution.
- **Horizontally Split Casing**—Upper half can be removed in one piece to remove rotor... inspections quickly made using light lifting equipment.
- **Renewable Labyrinth Seals**—Of honeycomb construction... minimize leakage at all close clearance points on turbine shaft.
- **Proved Reliability**—Materials of construction and important components such as turbine blade root design, turbine discs, journal bearings and axial compressor based on broad Clark experience in building heavy duty gas turbines.



Unitized combustion chamber with two parallel burners, each enclosed in a liner of high temperature nickel chrome alloy.



Single rotor is supported by two journal bearings for greatest simplicity. Horizontally split housing provides easy accessibility.



Rotor is statically and dynamically balanced for optimum performance. Turbine blades are of high temperature forged steel. Air streams cool turbine blade roots and both sides of discs.

You are invited to get full details on how Clark 305 Gas Turbines can bring you lower first cost, reduced floor space and installation costs, plus dependable, economical performance. Contact your nearest Clark representative or write for Bulletin 186.

CLARK BROS. CO., OLEAN, N. Y.

CLARK® DRESSER INDUSTRIES INC.
OIL • GAS • CHEMICAL
ELECTRONIC • INDUSTRIAL

Selecting A Motor Drive For A Hazardous Area?

Here's how
TEIGF motors
by E-M
provide safe, dependable, economical power

Faced with the problem of driving hydrogen compressors in atmospheres which might contain hydrocarbons at their Baltimore refinery, engineers of Esso Standard Oil Company turned to TEIGF (Totally Enclosed Inert Gas Filled) Motors. Horsepower requirements exceeded the practicable limits under which explosion-proof motors could be used.

An important consideration was getting the greatest possible drive economy while operating safely in a possible hydrogen atmosphere. Three E-M 350 hp, 390 rpm TEIGF Motors are on duty at Esso Standard Oil Company fulfilling these important qualifications.

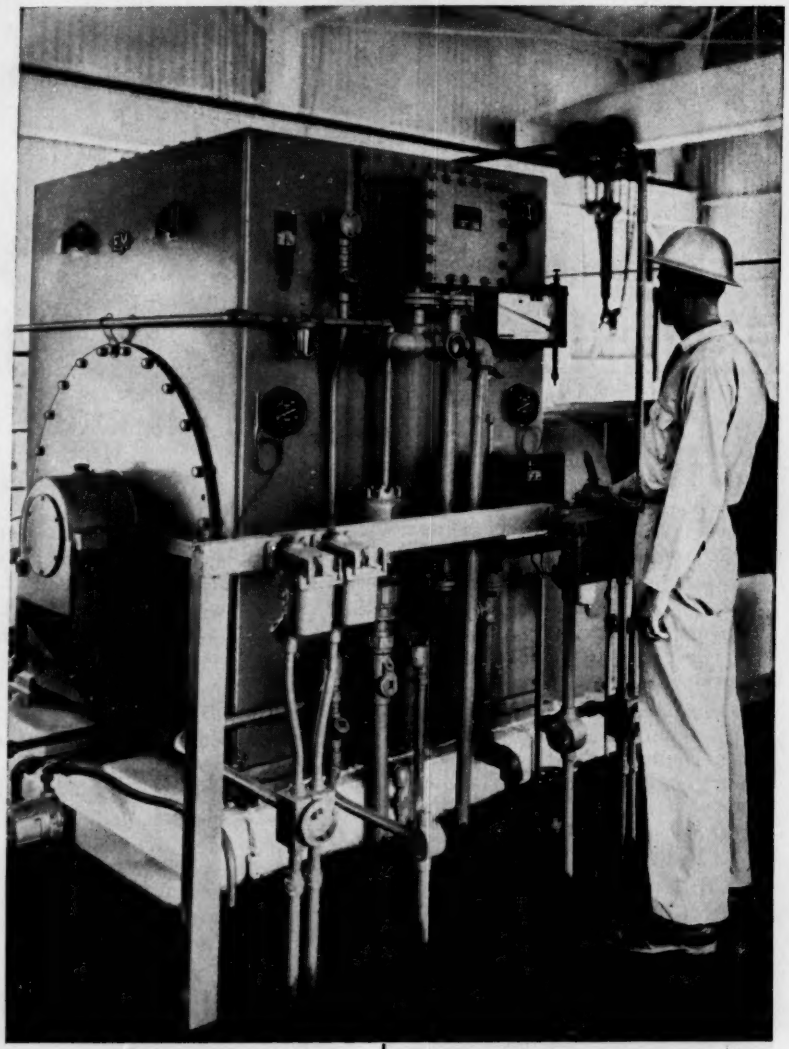
For Esso Standard Oil Company and other companies with similar problems, these E-M Motors offer three main groups of advantages:

1. SAFETY — Within the motor enclosure, inert gas pressure above atmospheric keeps explosive hydrogen *out*. A series of features help accomplish complete safety . . . inert gas pressure gauges . . . temperature gauges . . . purging valves, etc. and a full line of optional equipment. The E-M TEIGF Motor can be "customized" to meet your needs exactly.

2. RUGGED DEPENDABILITY. E-M uses specially designed "box type" frames of heavy-duty plate steel reinforced with heavy bar-stock ribs. They cannot twist or distort. Air gap is accurate and permanent, as all frame welding is completed before precision boring. Ventilating gas passages are carefully engineered to provide unimpeded gas flow for optimum cooling.

3. ECONOMICAL OPERATION. In E-M TEIGF Motors, gas loss is lower than commercially accepted standards. Specially designed shaft seals are oil-pressure gas-sealed bearing type, virtually non-wearing. Where bolts enter outside casing, E-M engineers specify blind holes . . . tapping and drilling are done *into* casing, not through. Operating and maintenance costs are at a minimum.

Consult your nearest E-M sales engineer, or write the factory for TEIGF Motor Bulletin No. 226.



TYPICAL STANDARD FEATURES INCLUDE:

1. Top-mounted gas-to-water cooler for use with suitable cooling water supply.
2. Forced-feed lubricated bearings and oil-pressure gas seals.
3. Oil pump, motor and oil filter. (Can be supplied optionally inside enclosure.)
4. Inert-gas temperature gauge.
5. Inert-gas pressure gauge.

(additional features shown in Bulletin No. 226)

TYPICAL OPTIONAL FEATURES INCLUDE:

1. Water cooler with double-tube construction for added protection against leakage.
2. Liquid level detector switch. Accumulation of moisture within motor sounds alarm or shuts down motor.
3. Bearing temperature relays, to sound alarm or shut down motor.
4. Explosion-proof motor terminal pothead or inert-gas filled terminal box.
5. Water flow indicator. Can be adapted for use with pneumatic-type regulating device.

ELECTRIC MACHINERY MFG. COMPANY
MINNEAPOLIS 13, MINNESOTA

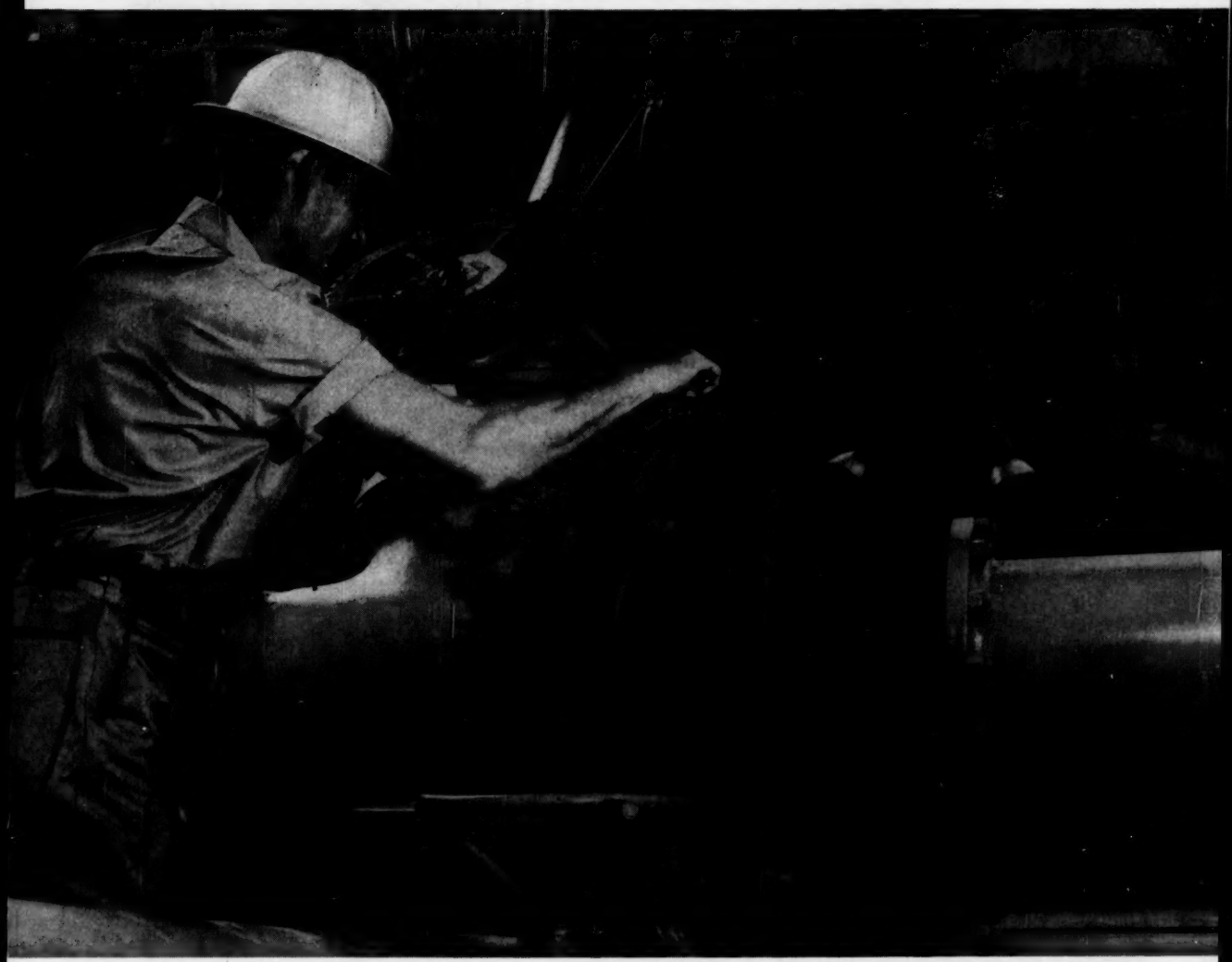
Specialists in making motors do
EXACTLY WHAT YOU WANT THEM TO

THIS WORK-HORSE VALVE WILL SAVE YOU MONEY!

ACF Lubricated Plug Valve

You will save on purchase price and in operating costs with the ACF Lubricated Plug Valve. Thousands of others have done the same and are successfully using this versatile valve in chemical plants, sewage plants, paper mills, oil production, mining operations and steel mills . . . it's a long list of applications. A cylindrical plug — like a journal in a well-oiled bearing — can only rotate, can't wedge and can't unseat. The ACF Lubricated Plug Valve may be installed in any position, fits in the smallest possible space. It can be serviced quickly, requires little attention. The efficient lubrication system holds corrosion to a minimum. Send for Catalog 400, P. O. Box 2117, Houston 1, Texas.

WHEN SO MUCH DEPENDS ON A VALVE . . . SPECIFY W-K-M



W-K-M DIVISION

ACF INDUSTRIES

Is it viscous... abrasive... corrosive?

Aldrich can pump it!

Are you working with hard-to-handle abrasive, corrosive, viscous or highly compressible liquids at high pressures? Are you running into crippling downtime, cost after cost? Get in touch with Aldrich!

Our specialty is the *hard-to-crack* problem in high-pressure pumps. No one has worked through as many tough assignments in such a wide range of applications as we. No one can approach your problem with as much experience at the start. In fact, chances are good that the pump you are looking for has already been developed at Aldrich for an application similar to yours.

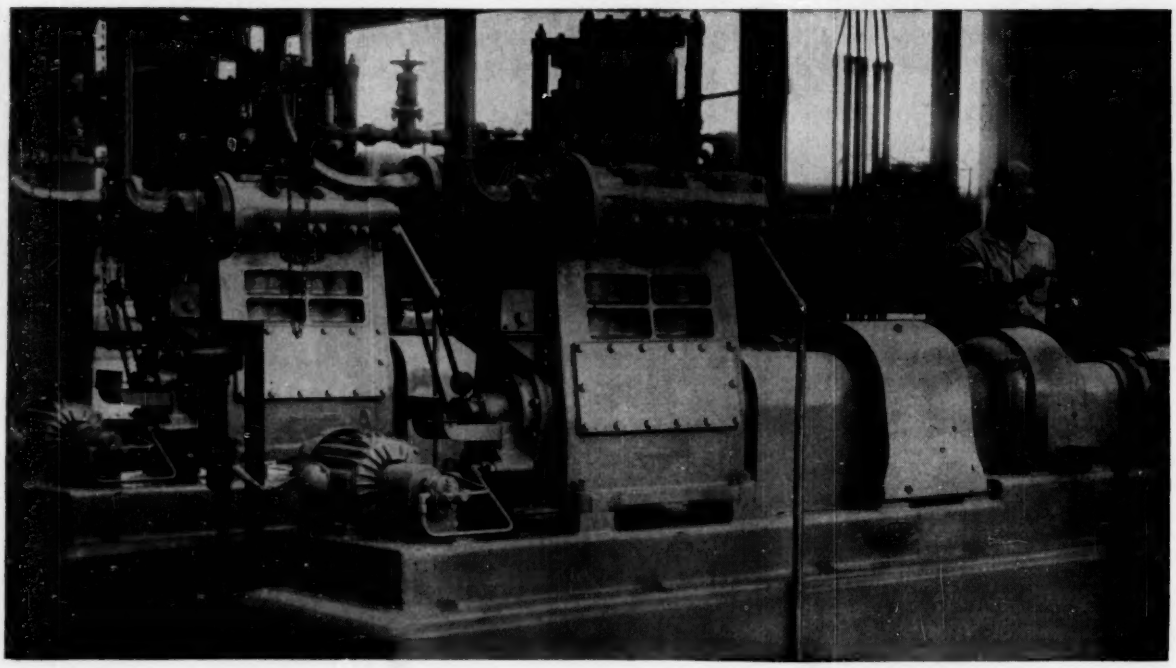
Aldrich pumps are handling such chemicals as: anhydrous ammonia, brine, caustic catalysts, caustics in 50% solution, liquid CO_2, diethylene glycol, di-propargyl ether, hydrocarbons, methanol, amine, naphtha, nitric acid, 9000 SSU oil, silica gel, sodium hypochlorite, sulfuric acid and carbamate.

In addition to getting dependable pump performance from Aldrich, you'll get *service*, geared to the pump user's urgent need to maintain operations. We stock parts for every standard pump we produce in eleven cities in the U.S. and Canada, and give top priority to parts for special pumps.

Write us about your pumping problem today. Sizes range from 25 to 2500 hp, pressures to 50,000 psi. Aldrich Pump Company, 10 Gordon St., Allentown, Pa.

The tough pumping problems go to

ALDRICH



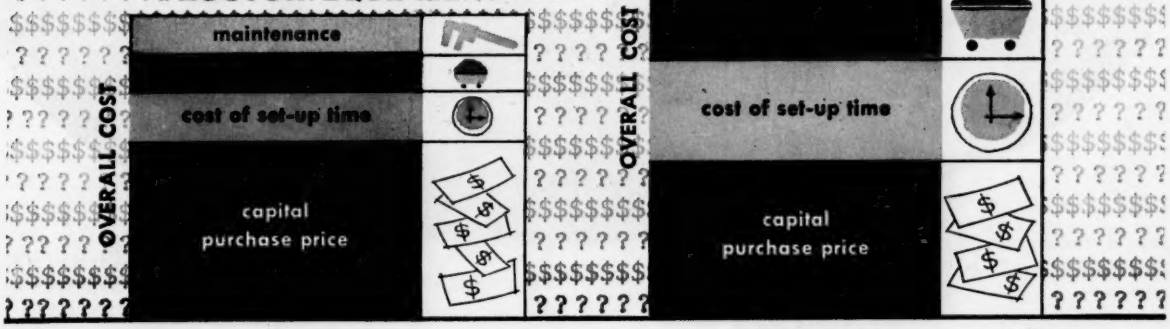
MODERNIZING WITH NEW EQUIPMENT?

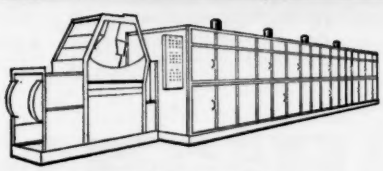
what will the REAL cost be?

REAL COST =

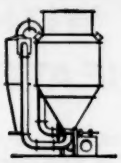
CAPITAL COST
+
INSTALLATION COST
+
AVOIDABLE WASTE
+
MAINTENANCE
+
DELAYED PRODUCTION

The purchase price can be the least of these over the years you will operate the equipment. PROCTOR users agree that the comparison of *real costs* often looks like this . . .

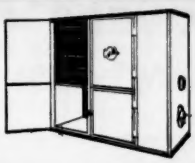




CONVEYOR DRYERS



SPRAY DRYERS



TRAY DRYERS

TRUCK DRYERS

Write for bulletin #443.

See our insert in Chemical Engineering Catalog.

Proctor & Schwartz will be happy to show you how buying Proctor equipment will cost you less.

Proctor®

PROCTOR & SCHWARTZ, INC.

PHILADELPHIA 20, PA.

This 25' Ljungstrom rotor will contain a total heating surface of 128,000 sq ft. Continuous heat recovery by this unit will boost the temperature of incoming combustion air from 100°F to 585°F. Every 45-50°F thus returned as preheat increases boiler efficiency about 1%.

DOW RECOVERS 425°F WITH LJUNGSTROM® AIR PREHEATER

When Dow Chemical Company's Westside Power House at Midland, Mich., starts up their new 650,000 lb/hr boiler, more than half the waste heat will be *recovered* by a Ljungstrom Air Preheater. Dow's newest Ljungstrom (this is the eighth in their system) was designed to lower stack gas temperature from 700°F to 275°F, thus *recovering 425°F.* As a direct result, company engineers expect at least 10% reduction in fuel costs.

On process stills or boilers—or wherever large volumes of heat are involved—Ljungstrom Air Preheaters improve combustion, make fuel burn more completely. It's possible to save as much as 20% on fuel.

***All* major public utilities** use Ljungstroms; as do many major chemical and petroleum processing companies. Chances are, you, too, could benefit. For additional information, call or write The Air Preheater Corporation, specifying type of application.

THE AIR PREHEATER CORPORATION

60 East 42nd Street, New York 17, N.Y.

PUMP MAINTENANCE... as simple as this?

A wad of waste is usually all that's needed to keep a Deming pump at top performance for years. Some people don't even bother to wipe 'em!

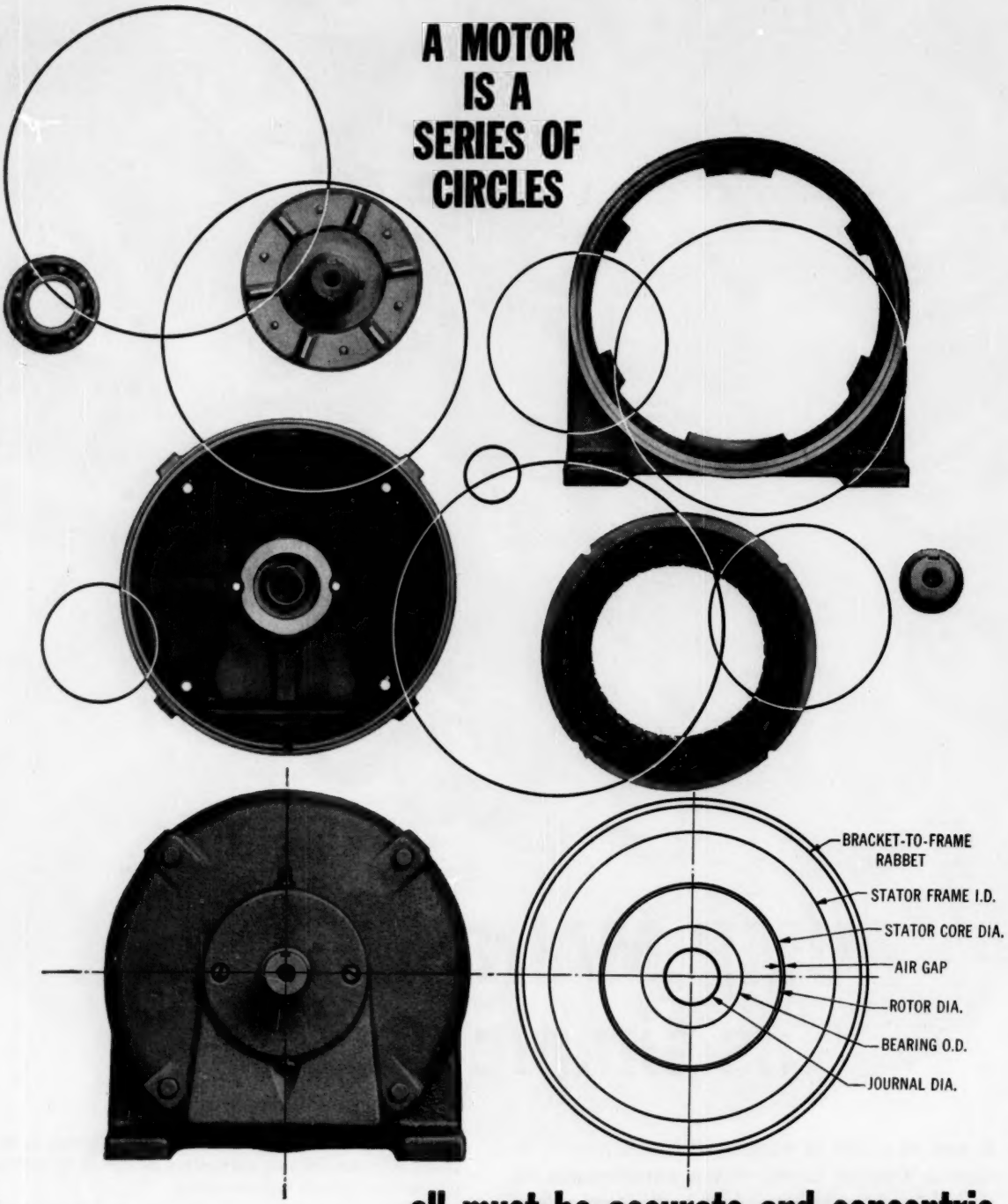
Dependable Demings save you money in other ways, too. When routine servicing is performed, spare parts inventory is light because Deming parts are standardized and readily interchangeable. Plant expansion is less costly because Deming pumps are designed for adaptation to your growth requirements.

Deming rotary and sump pumps, end suction and vertical immersion process pumps are of special interest to the processing industries. For complete descriptive literature, just mail the coupon.

THE DEMING CO.
687 Broadway • Salem, Ohio

Please send me catalogs on: (type)_____ pumps
for (application) _____
NAME _____
ADDRESS _____
CITY _____ ZONE ____ STATE _____

A MOTOR IS A SERIES OF CIRCLES



all must be accurate and concentric

In manufacturing Elliott Crocker-Wheeler motors, a dozen critical "circles" are formed accurately and concentrically through unique and extraordinarily precise production methods. The result is exact alignment of all parts, true and uniform air gap, free-spinning rotor, quiet, cool, dependable operation.

■ *Elliott Crocker-Wheeler integral-hp a-c and d-c motors—from smallest to largest—are offered in all conventional enclosures and modifications; with insulation to suit the application, including* EPACSEAL *epoxy insulation for use where conditions are most severe.*

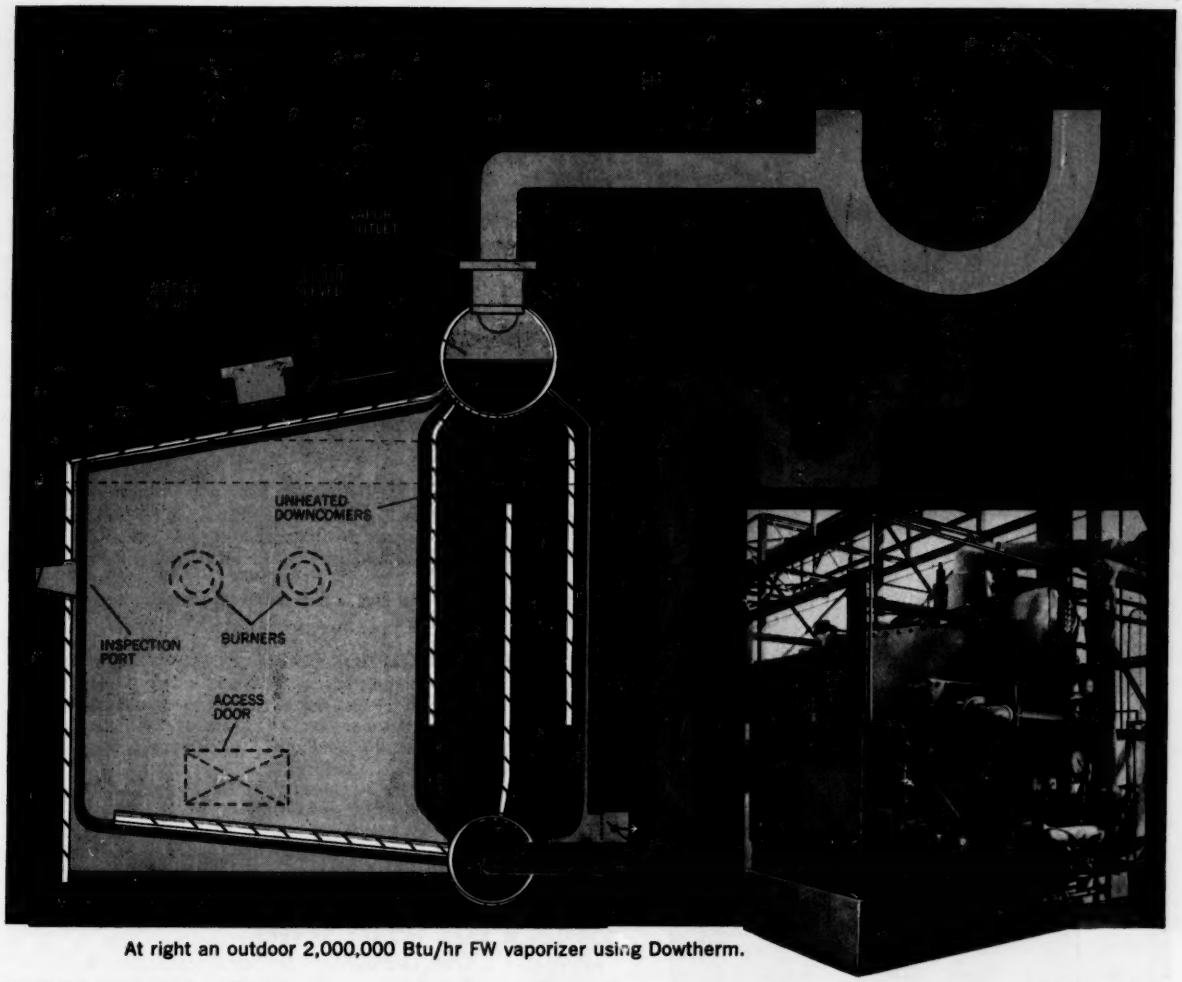
W1-3

ELLIOTT COMPANY

GENERAL OFFICES: JEANNETTE, PENNSYLVANIA

PLANTS AT: Jeannette and Ridgway, Pa.; Springfield, Ohio

TURBINES · GENERATORS · MOTORS · COMPRESSORS · TURBOCHARGERS · EJECTORS · STRAINERS · TUBE CLEANERS



At right an outdoor 2,000,000 Btu/hr FW vaporizer using Dowtherm.

FW vaporizers...less to buy...less to maintain

By surveying and understanding your entire process, Foster Wheeler engineers are able to tailor your vaporizer and its auxiliaries exactly to your needs. By thus avoiding over- and under-design, you are assured minimum first cost consistent with dependable economic performance.

FW natural circulation vaporizers and their adaptability to gravity return systems mean fewer moving parts, lower power consumption, reduced pump cost and maintenance, and greater accessibility. Such units also use a smaller quantity of valuable heating medium.

In addition, FW vaporizers offer unusually sensitive heat control by eliminating flash-down to achieve precise final temperatures. This means instant response to temperature variation and reduced degradation of the heating medium . . . protecting your investment in it.

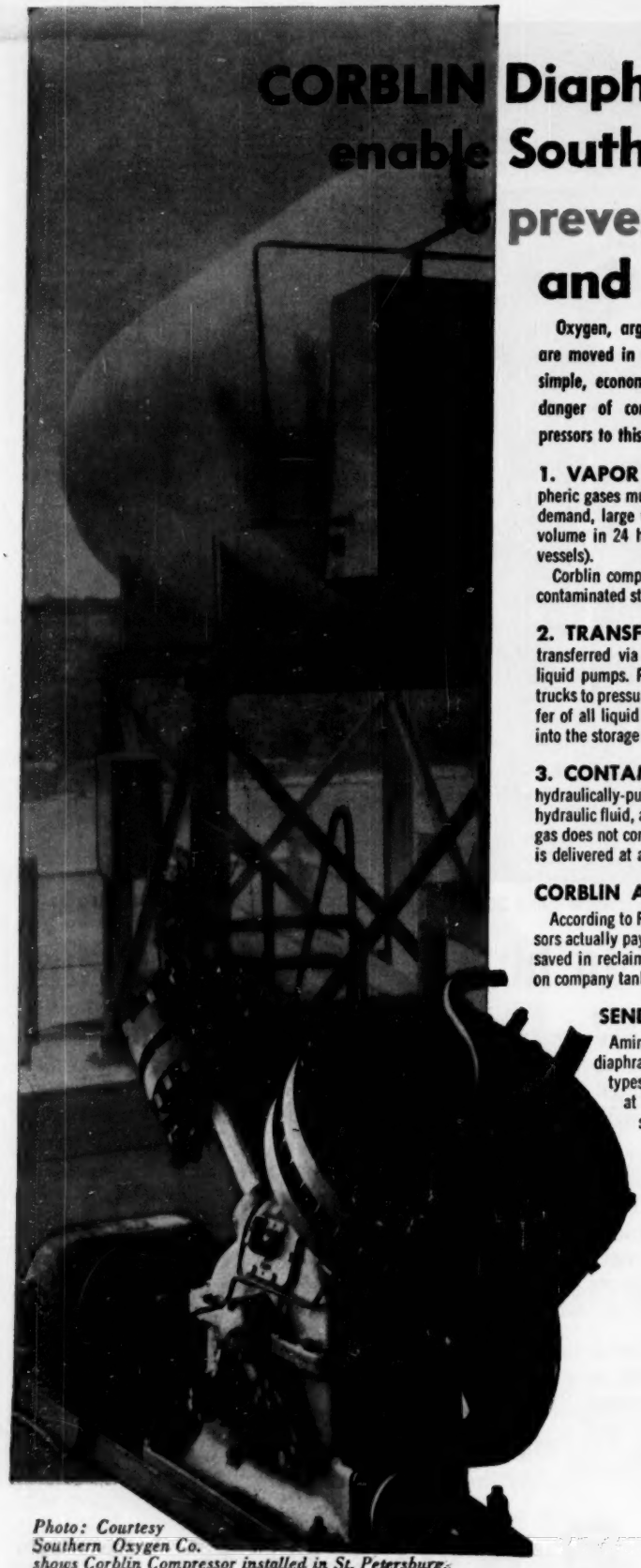
FW vaporizers do all of this with fewer control devices and less auxiliary equipment than recommended with other vaporizers. With less to buy and maintain, both first cost and operating overhead are held down. By surveying and understanding your entire process the most practical piping arrangements can be made to allow for optimum heat transfer as well as operator convenience.

Over the last 26 years Foster Wheeler has supplied over 700 organic heating systems for every application and capacity, from the smallest on up to single units delivering in excess of 50,000,000 Btu/hr. Get full benefit from this broad experience by discussing your requirements with Foster Wheeler Corporation, 666 Fifth Avenue, New York 19, New York.

Heat Engineered products, plants and processes . . . for the world's industrial progress.

FOSTER WHEELER

NEW YORK TORONTO LONDON PARIS MILAN TOKYO



CORBLIN Diaphragm Compressors enable Southern Oxygen Co. prevent product waste and contamination

Oxygen, argon and nitrogen manufactured by the Southern Oxygen Co. are moved in liquid form throughout the country by tank truck. To ensure simple, economical handling of the gas at distribution points, without the danger of contamination, Aminco supplied Corblin diaphragm-type compressors to this company for:

1. VAPOR RECOVERY: At distribution points where liquified atmospheric gases must be stored for long periods of time due to small or intermittent demand, large volumes of gas were previously lost through evaporation (1% of volume in 24 hours, vented to atmosphere through relief valves in the storage vessels).

Corblin compressors are now used to recover this gas and pump it in an uncontaminated state into cylinders.

2. TRANSFER OF LIQUIFIED GAS: Liquid from the tank trucks is transferred via Corblin compressors into storage vessels without the need for liquid pumps. Residual vapors are first pumped from storage vessels into tank trucks to pressurize the liquid therein and force it into the storage tank. After transfer of all liquid from the trucks, the valves may be reversed to suck vapor back into the storage vessel.

3. CONTAMINATION-FREE HANDLING: Gas is compressed by hydraulically-pulsed metal diaphragms which act as a barrier between gas and hydraulic fluid, and as a gasket to prevent leakage from the compressor. Thus, the gas does not come into contact with lubricants or other contaminating agents, and is delivered at a purity level of 99.9998%.

CORBLIN A REAL MONEY SAVER!

According to R. L. Swope, Chief Engineer of Southern Oxygen, Corblin Compressors actually pay for themselves in a relatively short period of time through dollars saved in reclaiming formerly-unrecoverable gas, and in the reduction of mileage on company tank trucks.

SEND FOR BULLETIN 4071— C

Aminco will forward on request this Bulletin describing Corblin diaphragm-type pumps and compressors. Units are available for all types of gases including highly toxic, corrosive and radioactive gas, at pressures to 30,000 p.s.i., and capacities to several hundred s.c.f.m. under certain conditions of operation. Units are also available for pumping all types of liquids.

AMINCO

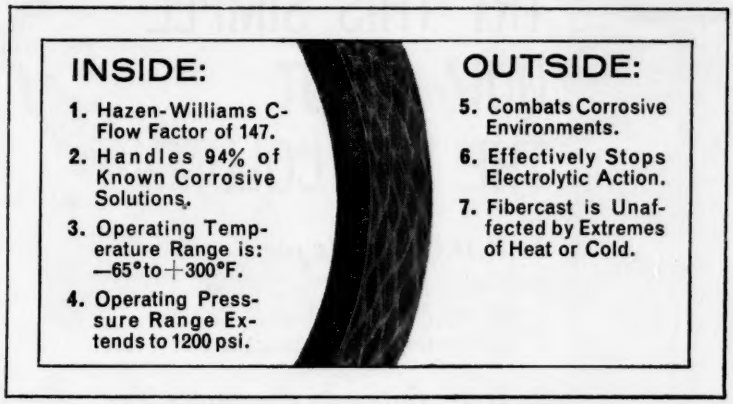
AMERICAN INSTRUMENT CO., INC.

8030 Georgia Ave., Silver Spring, Md.

AMINCO

Exclusive distributor of Corblin Pumps and Compressors in North America

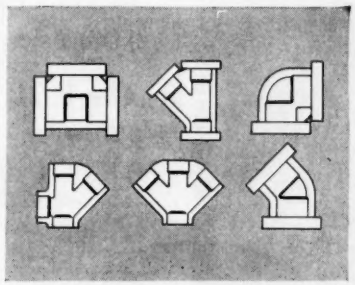
Photo: Courtesy Southern Oxygen Co. shows Corblin Compressor installed in St. Petersburg, Fla. plant. Liquid argon storage tank in background.


INSIDE:
1. Hazen-Williams C-Flow Factor of 147.
2. Handles 94% of Known Corrosive Solutions.
3. Operating Temperature Range is: —65°to+300°F.
4. Operating Pressure Range Extends to 1200 psi.
OUTSIDE:
5. Combats Corrosive Environments.
6. Effectively Stops Electrolytic Action.
7. Fibercast is Unaffected by Extremes of Heat or Cold.

How Fibercast pipe is better built to combat corrosion...*inside and out!*

Years of research and development have perfected the most versatile pipe tested for heat, pressure and corrosive applications. Years of actual field use prove its long service life! Here are the reasons why:

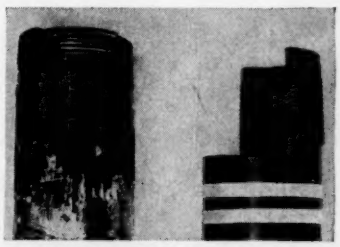
1. FIBERCAST has a ceramic-smooth interior with a Hazen-Williams C Flow Factor of 147. Aids flow, resists deposit build-up.
2. FIBERCAST handles 94% of all known corrosive solutions. It is not impaired by acids, alkalies, salts, other damaging chemicals.
3. FIBERCAST withstands any temperature range from —65° to +300°F. This is a wider operating temperature range than any nonmetallic pipe.
4. FIBERCAST provides superior resistance to high pressures. Its operating range extends to 1200 psi.
5. FIBERCAST has built-in inhibitors that combat the most highly corrosive environments and seals out contaminants.
6. FIBERCAST provides resistance to high tension forces. It is inert—stops electrochemical corrosion, forms an extremely durable dielectric shield.
7. FIBERCAST is unaffected by summer heat or winter cold; has superior resistance to severe atmospheres and weathering.



Fibercast has the world's most complete stock of standard fittings, as well as couplings designed and made to order for individual requirements.

The effectiveness and long-term durability of Fibercast pipe are the result of built-in inhibitors—high tensile glass fibers, imbedded and bonded by heat in epoxy resin, and centrifugal casting. It gives Fibercast a high degree of smoothness, ruggedness, permanence—and superior resistance to exposures involved in the most difficult corrosive, pressure and temperature conditions.

Reliability with true economy is built in—inside and out—and throughout the inner core of the casing thickness. This unique combination of benefits is not found in any other kind of pipe: rubber, glass, plastic, steel, stainless, aluminum, asbestos, brass or copper tubing.



Fibercast Tubing (right) used to suspend a 1,200 lb. pump for 3 years in a salt water supply well. *There was no loss in strength.* The damaged plastic-coated steel nipple (left) was used in the same installation, failed after 3 months' service.

Fibercast is available for all lines from 2″ tubing through 8″ pipe for service from—65° to +300°F. For more information mail coupon.

FIBERCAST COMPANY
Box 727, Sand Springs, Oklahoma

Please send me further information about Fibercast Tube and Pipe. CE-61

Name _____

Firm _____

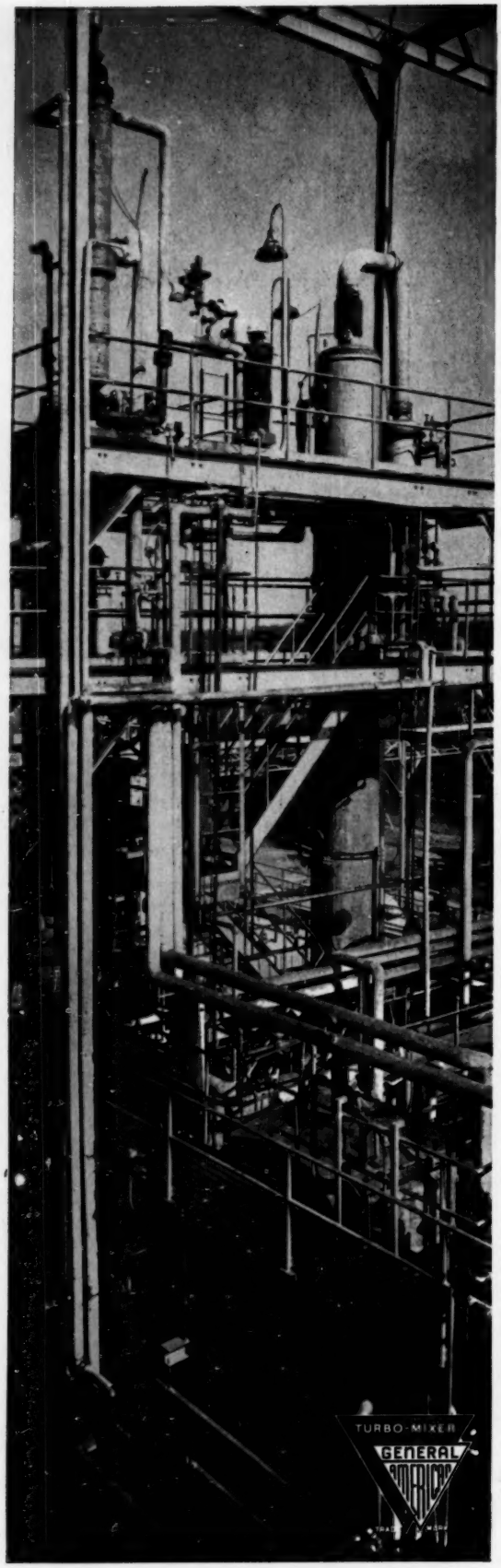
Title _____

Type of Business _____

Address _____

City _____ Zone _____ State _____

FIBERCAST® COMPANY
A DIVISION OF **Youngstown** SHEET AND TUBE COMPANY



TRY THIS SIMPLE QUIZ ABOUT THE **RDC** COLUMN

1. *R.D.C. stands for*

- ☐ a) Rapid Dispersion Column
- ☐ b) Recycle Displacement Column
- ☐ c) Rotating Disc Contactor

2. *RDC Columns are made by*

- ☐ a) 6 different manufacturers
- ☐ b) by one manufacturer
- ☐ c) by 10 manufacturers

3. *The RDC column has been used for*

- ☐ a) Separation of Hafnium from Zirconium
- ☐ b) Caustic extraction of acids from organics
- ☐ c) Caffein and vanillin extraction

4. *The RDC column can be used for*

- ☐ a) liquid-liquid extraction
- ☐ b) liquid-solid extraction
- ☐ c) liquid-slurry extraction

5. *The RDC column has which of these advantages*

- ☐ a) High volumetric efficiency
- ☐ b) No interstage coalescing or external settling
- ☐ c) Low power requirements

Answers

1. (C) Rotating Disc Contactor.

2. (B) RDC columns are made for the process industries exclusively by General American, and on a non-exclusive basis for the petroleum industry.

3. (A), (B) and (C). For a complete list of typical systems in service, contact General American.

4. (A), (B) and (C) again. The RDC column is one of the most versatile tools available for extraction processing.

5. (We did it again—all three are correct).

If you'd like more information on the RDC column and the many advantages it offers, send for Bulletin T-1159. You'll find it pays to plan with General American.

Process Equipment Division—Turbo-Mixers
GENERAL AMERICAN TRANSPORTATION CORPORATION
135 South LaSalle Street • Chicago 3, Illinois
Offices in principal cities

A Y Globe that challenges comparison shows it pays to

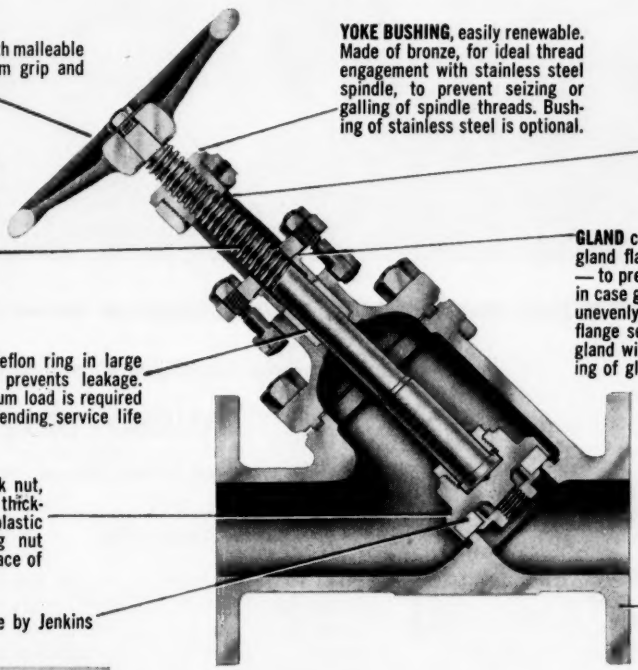
Specify JENKINS for STAINLESS STEEL Valves, too

Want the "best buy" in Stainless Steel Y Globe Valves? Compare this Jenkins Fig. 1335 with any on the market. You'll conclude that it's hard to beat Jenkins at making valves, no matter what the material.

You'll find genuine superiority of design and construction in the features shown here. But no picture can show the quality of the castings . . . the precision machining . . . the rigid inspection and testing that have gone into this valve. All of these are as important as design and metal alloys in assuring long, dependable, economical valve service. And, all of them are up to the peak standards for which Jenkins has been known for almost a century.

SEND FOR NEW CATALOG of Jenkins Stainless Steel Valves, in patterns and alloys that satisfy the requirements of practically all corrosive services.

These Jenkins Valves meet valve industry specifications and the high standards established by leading users of stainless steel valves.



WHEEL of high strength malleable iron designed for firm grip and easy operation.

SPINDLE of large diameter and dense structure has high resistance to wear and torsion strains. Easy, tight closing is assured by long, precision machined thread bearing surfaces. A beveled shoulder provides backseating against inside of bonnet, permitting repacking under pressure.

PACKING A Teflon ring in large packing box prevents leakage. Only a minimum load is required on gland, extending service life of packing.

DISC HOLDER, held by lock nut, has depth equal to disc thickness, preventing flow of plastic disc. Wide disc retaining nut covers all but seating surface of Teflon disc.

DISC is Teflon made by Jenkins

YOKE BUSHING, easily renewable. Made of bronze, for ideal thread engagement with stainless steel spindle, to prevent seizing or galling of spindle threads. Bushing of stainless steel is optional.

YOKE BONNET, a single unit, has liberal space between yoke arms for easy access to packing box. Tongue and groove joint with body makes a pressure-tight seal with less tightening on the bolts, and eliminates possibility of blowing out the Teflon gasket.

GLAND consists of two pieces — gland flange and gland follower — to prevent binding of follower in case gland bolts are tightened unevenly. Crowned surface of flange secures tightness against gland without excessive tightening of gland nuts.

BODY Through-port design for full, free flow. Liberal seat height permits repeated refacing. Cast on body are directional arrow and bosses for drain connections. End flanges conform to M.S.S. specifications.

JENKINS VALVES

LOOK FOR THE JENKINS DIAMOND

Sold Through Leading Distributors Everywhere

JENKINS BROS., 100 Park Avenue, New York 17, N. Y.

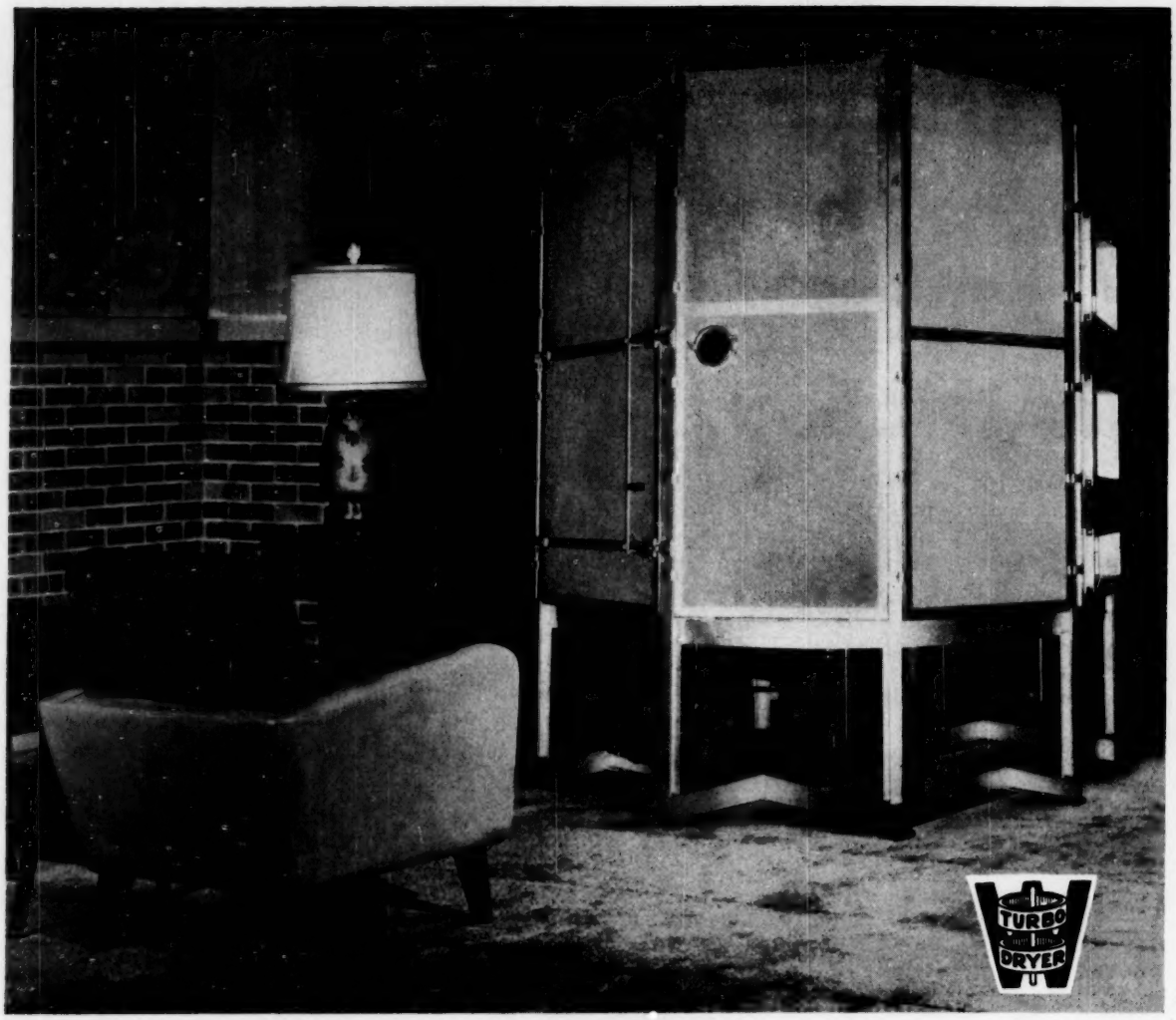
☐ Send the new stainless steel valve catalog

☐ Have a representative call on me

NAME & TITLE.....

COMPANY.....

ADDRESS.....



Speaking of carefree and clean operation — — —

Wyssmont announces

the newly redesigned, packaged

TURBO - DRYERS®

12 major structural and mechanical improvements make for

- **Dust Free Operation**
- **Easy Accessibility**
- **Simple Maintenance**
- **Reliable Operation**

Units are smoke-bomb tested for tightness before leaving shop. Remember TURBO-DRYERS® handle heat sensitive and fragile products - - - drying is uniform and no dust collectors are required - - - ideal for small production or pilot operation.
For more information on Wyssmont equipment and methods consult your Chemical Engineering Catalogue.

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The Temperature Control Powered by the

IRREPRESSIBLE FORCE OF MERCURY–

for Accuracy with Rugged Dependability

All Partlow temperature controls are directly and positively actuated by mercury, the metal in liquid form whose reaction to changes in temperature is as predictable as it is powerful.

Unlike delicate electronic controllers, the mercury-actuated Partlow requires no outside power source. No amplifiers. No finicky levers. And no "babying"! With a Partlow you can be sure of getting accurate, dependable control even under extreme conditions of shock and vibration.

Mercury-actuation makes possible maximum design efficiency and simplicity too. The Partlow has fewer parts to go wrong. And fewer service problems (with less "down" time) should trouble occur. You can replace the thermal element of any Partlow control instantly, right at the job site, without recalibrating, fitting or factory adjustment.

Whatever the process or application, you'll find a Partlow temperature control to fit it dependably, economically, *precisely*. Mail coupon today.

See Partlow Section in Chemical Engineering Catalog

PARTLOW

TEMPERATURE CONTROLS

World Export:
Ad. Auriema, Inc., 85 Broad Street, New York 4, N. Y.

THE PARTLOW CORP., Dept. E-661
NEW HARTFORD, N. Y.

Please send condensed Catalog of Partlow temperature controls and allied equipment for industrial heating and refrigeration.

Name and Title .....

Company .....

Address .....

City and State .....

.....

THIS NEW MEDIUM RANGE CENTER LINE MOUNT PUMP WILL HANDLE VIRTUALLY ANY LIQUID USED IN A PROCESS PLANT

PEERLESS PUMP

Interchangeability feature of Peerless DMR pumps allows tailor made construction from standard parts to fit your plant's exact needs . . .

What's your pumping problem? Are you moving hydrocarbons, process chemicals or perhaps it's corrosive feedstocks that must be transferred. Then the Peerless DMR is the pump for you. Consider these reasons. The DMR will be assembled to handle your exact pumping needs. No need of compromising or re-vamping your intended plans. The DMR is a proven-in-use pump. You get a reliability factor you can be sure of. The integrated features of the DMR reduce need for large stocks of inventory parts—in some cases by as much as 85%. The DMR is an easy pump to apply. Installation is readily accomplished with little downtime. Long operating periods with minimum maintenance attention adds to the savings these pumps offer. And quick accessibility to interior parts simplifies servicing when and if required. What's more, the DMR has an attractive price tag that you will like. So get the full facts now. Write Peerless for a copy of Bulletin B-1610 which describes the new DMR pump in complete detail.

TYPE DMR CHARACTERISTICS

TYPE: Single stage, horizontal, end-suction, top discharge. **DISCHARGE SIZES:** 1", 2", 3" on 8½" frame: 1", 2", 3", 4" on 10½" frame. **CAPACITIES:** Up to 900 gpm. **HEADS:** Up to 450 feet. **WORKING PRESSURE:** Up to 300 psig. **LIQUID TEMPERATURE:** Up to 450°F. **CONSTRUCTION MATERIALS:** Any machinable metal. Cast iron, carbon steel, and stainless steel liquid ends are carried in stock as standard. **DRIVES:** Electric motor or steam turbine. **LUBRICATION:** Oil lubricated bearing frame. **LIQUIDS HANDLED:** Virtually all liquids used in refinery and petrochemical processing.

Putting Ideas to Work

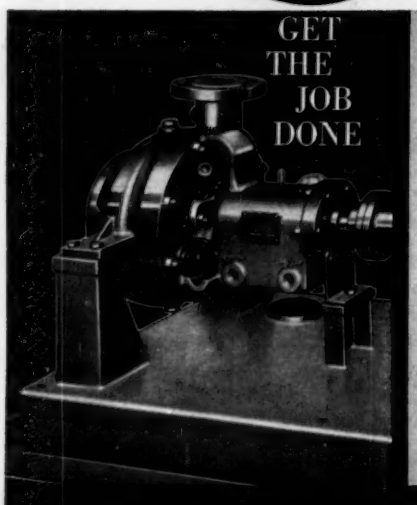
PEERLESS PUMP

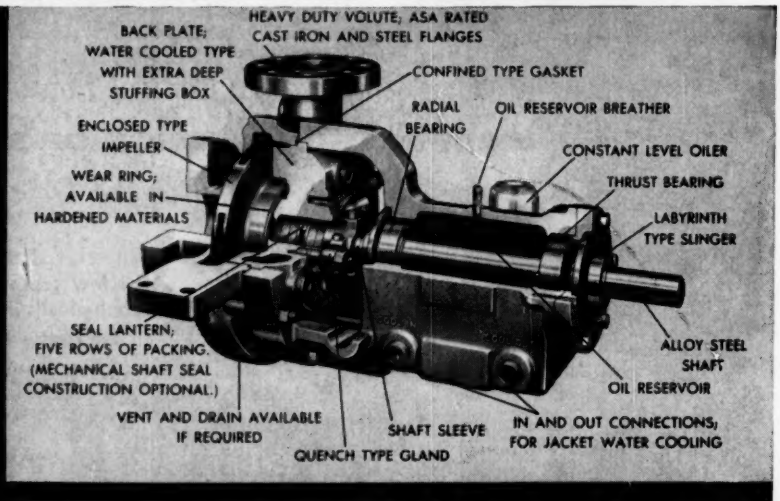
HYDRODYNAMICS DIVISION

Plants: Los Angeles 31 California, and Indianapolis 8, Indiana.

Offices: New York; Detroit; Chicago; Cleveland; Indianapolis; St. Louis; San Francisco; Atlanta; Plainview; Lubbock; Phoenix; Albuquerque; Los Angeles; Fresno.

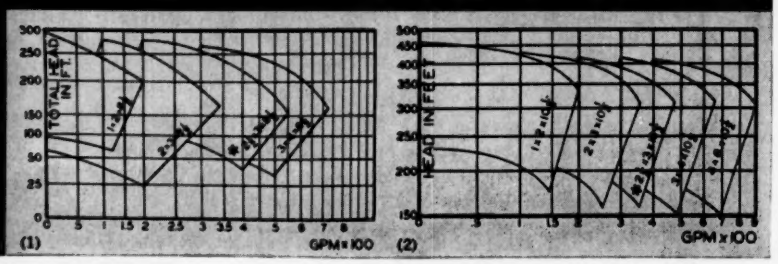
Distributors in principal cities. Consult your telephone directory.





PERFORMANCE CURVES
PEERLESS TYPE DMR PUMPS
8½" and 10½" at 3500 rpm

Peerless DMR Pumps are available with both 1750 and 3500 rpm drives. Shown at right are typical curves for (1) 8½"—3500 rpm, (2) 10½"—3500 rpm.



HARBISON-WALKER

DURO

acid-proof

TILE

For the most durable chemical resistant floors

Duro tile are dense and non-absorbent throughout their entire thickness and are not dependent upon a skin glaze for resistance to penetration by corrosive liquids. The smooth, non-glassy surface of Duro is good for traction and the avoidance of slippage. Surfaces can be textured if desired.

Duro is vitreous to the most desirable degree for high strength to withstand impact and abrasion and for maximum impermeability and resistance to chemical action. This combination of properties is attributable to its stabilized chemical composition of aluminum silicate which is exceedingly low in the more soluble basic fluxes, such as iron oxide and alkalies, the vacuum method of forming and the high temperature at which it is fired. Its mineral constituents are converted to the most stable forms of greatest insolubility in acids and various corrosive materials.

The light buff color of Duro, with freedom from the glare caused by glazed surfaces, contributes to the clean, sanitary appearance of the floors. The excellent workmanship of Duro tile and the variety of cove base shapes makes readily feasible a neat close fitting construction that is easy to keep clean.

Some typical applications for Duro in acid-proof floors are as follows:

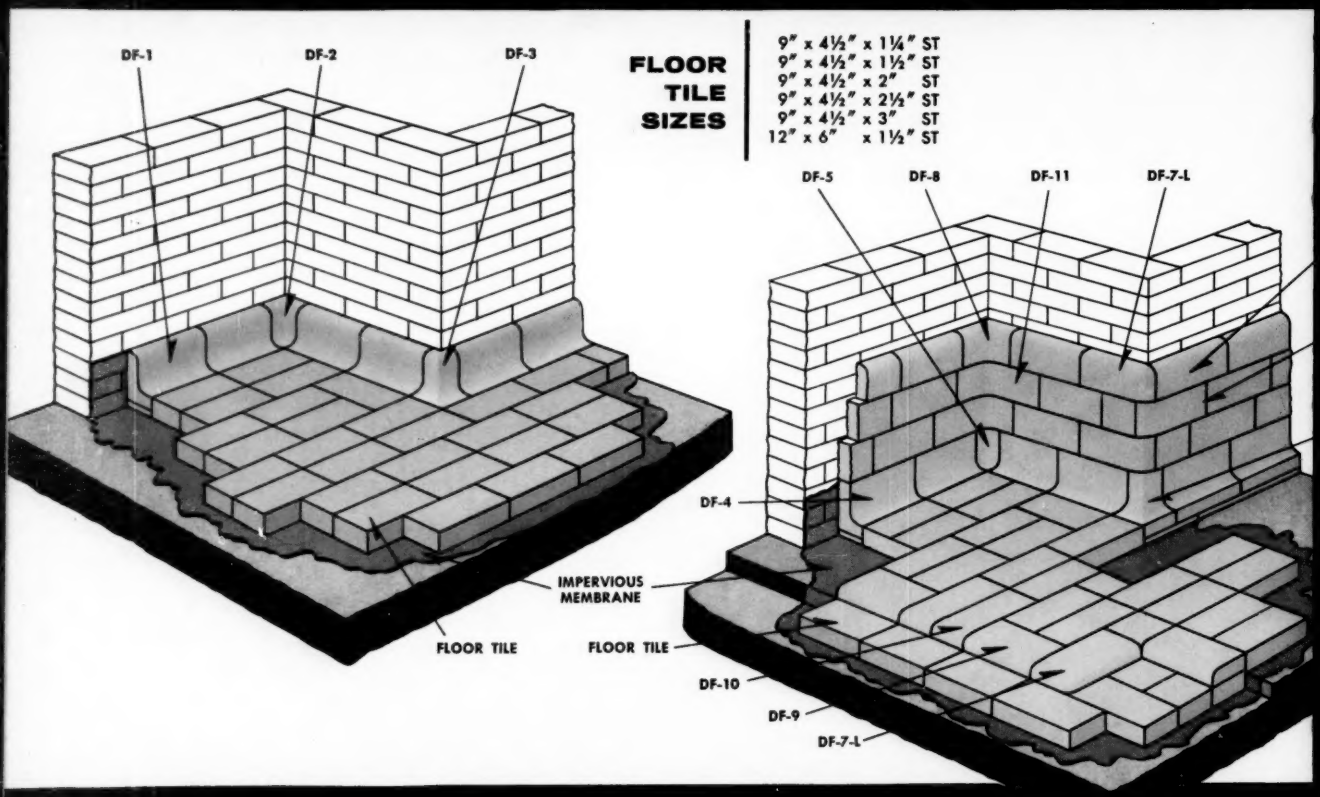
- Acid Rooms
- Bakeries
- Bottling Plants
- Breweries
- Chemical Plants
- Dairies
- Die Works
- Electroplating Plants
- Electrolytic Metal Refineries
- Food Processing Plants
- Galvanizing Departments
- Meat Packing Plants
- Metal Fabricating Plants
- Paper Mills
- Photoengraving Plants
- Rayon Plants
- Steel Pickling Plants
- Textile Mills

HARBISON-WALKER REFRACTORIES COMPANY

AND SUBSIDIARIES

Worlds Most Complete Refractories Service

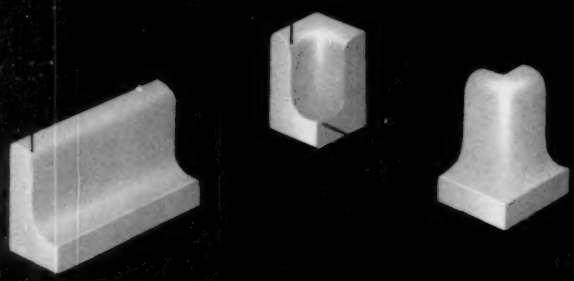
GENERAL OFFICES: PITTSBURGH 22, PENNSYLVANIA

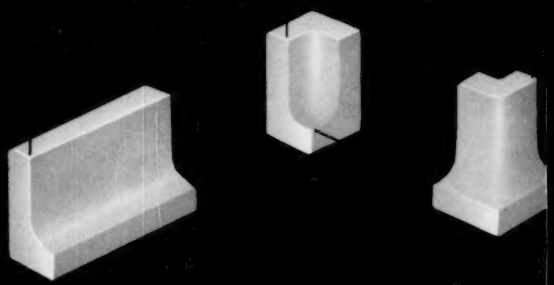


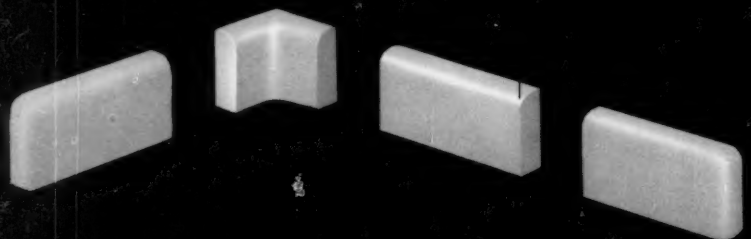
FLOOR TILE SIZES

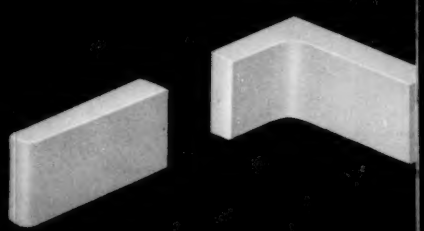
9" x 4½" x 1¼" ST
9" x 4½" x 1½" ST
9" x 4½" x 2" ST
9" x 4½" x 2½" ST
9" x 4½" x 3" ST
12" x 6" x 1½" ST

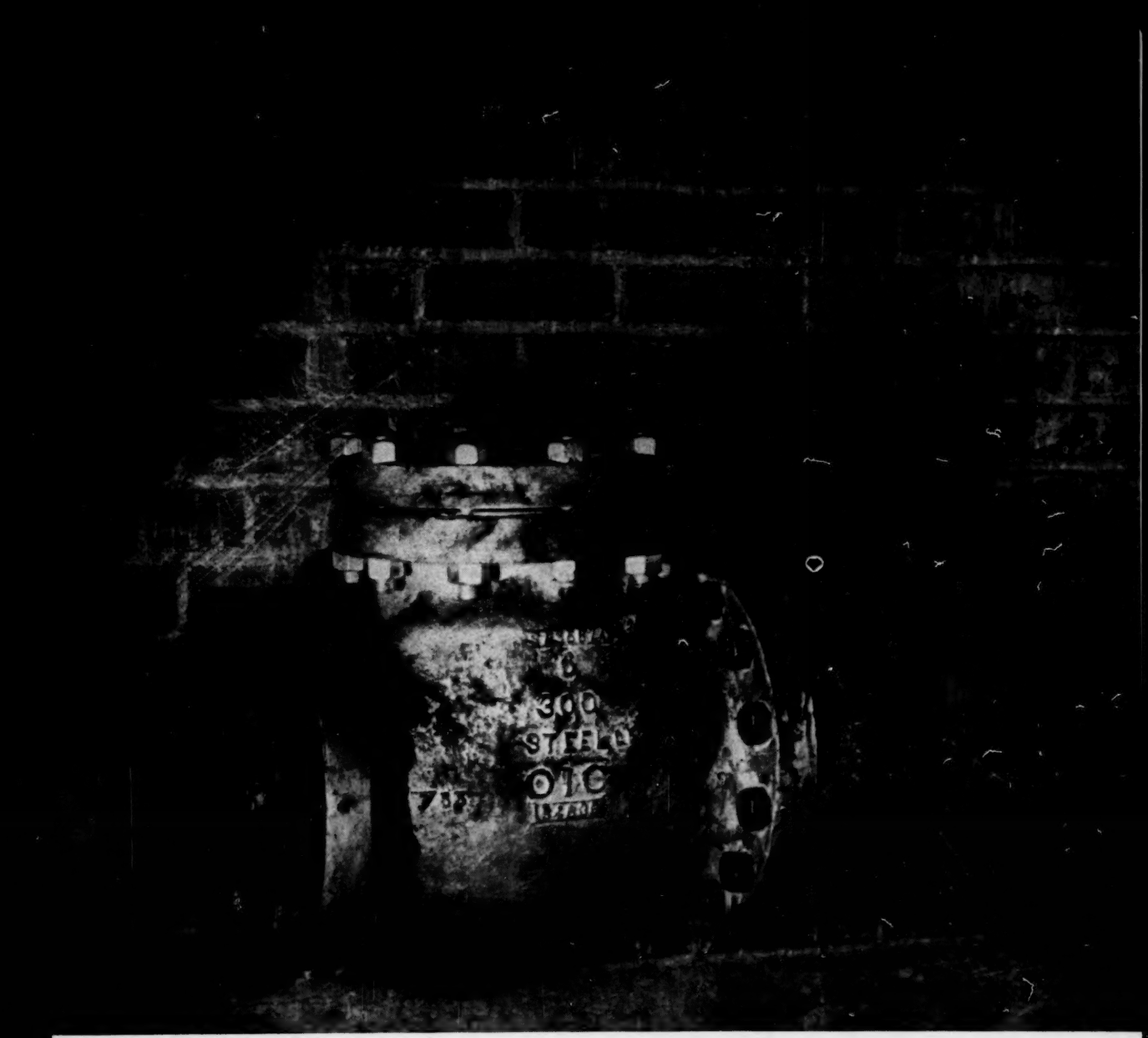
DIMENSIONS OF STANDARD DURO SHAPES











PORTRAIT OF DEPENDABILITY

Undisturbed cobwebs tell a powerful story! Day in and day out, OIC steel valves take strain, vibration, pressure changes and shock in their stride. From the outside you get no hint of the precise manufacturing tolerances that make this trouble-free performance possible. OIC steel valves are designed to handle your steam, chemicals or hydrocarbons with minimum maintenance and maximum cost savings. Of this you can be sure . . . OIC steel valves are built to operate with complete dependability.

THE FINEST VALVES AND DISTRIBUTOR SERVICE FROM OIC

OIC VALVES

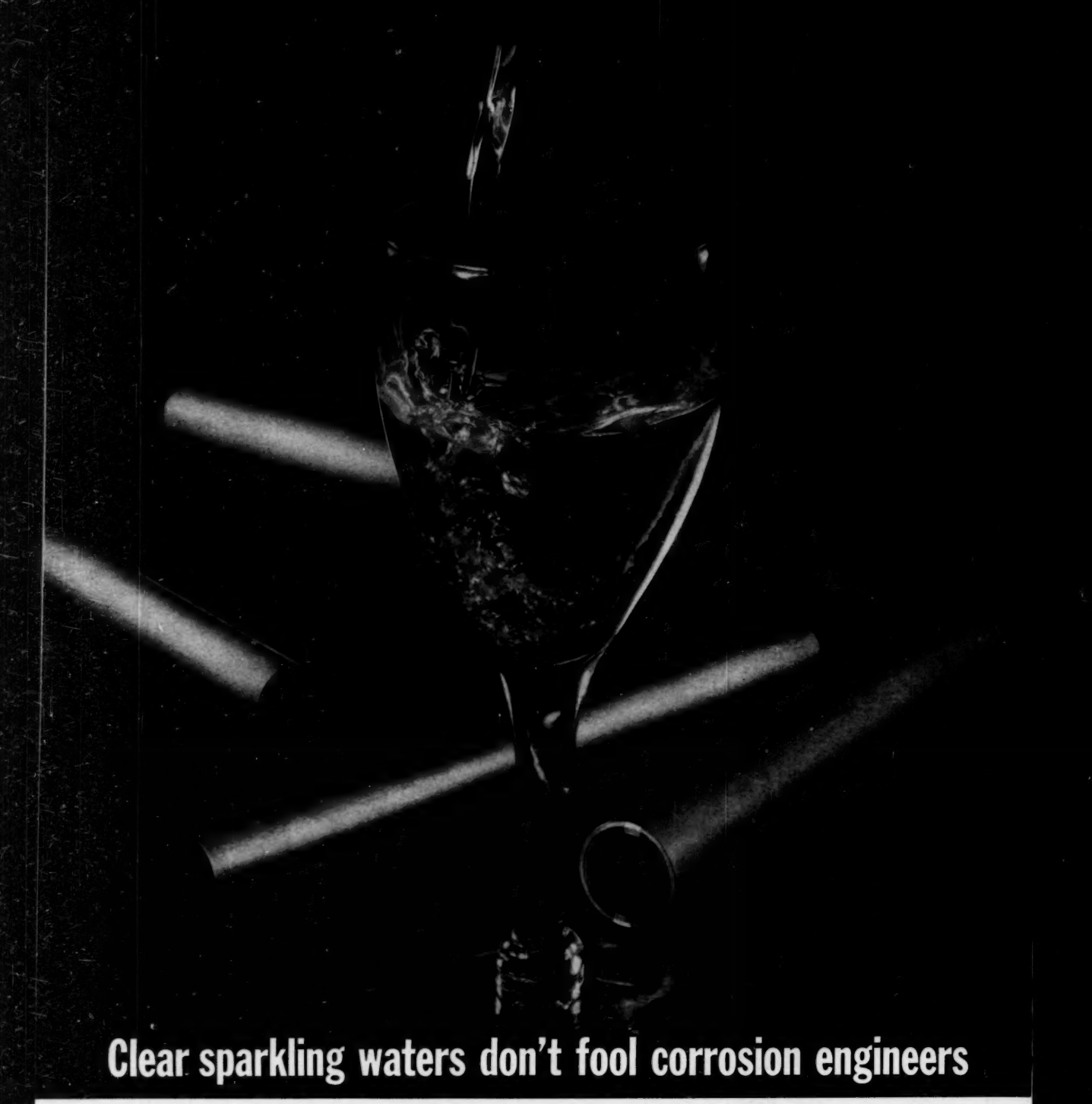
BRONZE, IRON,
FORGED STEEL,
CAST STEEL AND
DUCTILE IRON VALVES

INDUSTRIAL DISTRIBUTION — SERVING INDUSTRY ECONOMICALLY — THE RIGHT HAND OF PRODUCTION

THE OHIO INJECTOR COMPANY, WADSWORTH, OHIO

The Ohio Injector Company 10818-OIC
263 Main Street, Wadsworth, Ohio.
Your story interests me. Please send more information about valves used in my industry.

Name _____
Company _____
Product _____
Street _____
City _____ Zone ___ State _____



Clear sparkling waters don't fool corrosion engineers

Coupled with temperature, pressure and velocity, some waters can chew up condenser tubes faster than you would believe possible. Minute differences in oxygen, chemical or biological content give each a corrosive character of its own that calls for well-informed tube alloy selection.

Case histories in which tube life has been increased from months to *years*—or from years to many *more* years—are packed in Bridgeport's files. The training and experience of our corrosion specialists can help match the best tube alloy to your water supply—whether potable, saline, brackish or polluted.

Write for information on Bridgeport's regular or Duplex tubes—or call in a Bridgeport man for quick and practical assistance on your corrosion, erosion or bio-fouling problems.

Bridgeport condenser and heat exchanger tubes in over 50 metals and alloys:

INHIBITED ADMIRALTY
INHIBITED ALUMINUM BRASS
INHIBITED MUNTZ METAL
70-30 CUPRO NICKEL
90-10 CUPRO NICKEL
DEOXIDIZED ARSENICAL COPPER
INHIBITED ALUMINUM BRONZE
RED BRASS
ALLOY 77 MERCURY BRASS

...plus **DUPLEX TUBES**...in combinations of the above alloys, with carbon or stainless steel, aluminum, Monel,® nickel...or other metals.

BRIDGEPORT BRASS COMPANY

Bridgeport 2, Connecticut

Bridgeport

Acetic Acid
Acetates
1. Ethyl
2. Isopropyl
3. Amyl
4. Butyl
Acetone
Alcohol, Ethyl (grain)
Alcohol, Methyl (wood)
Alum (paper mill)
Aluminum Sulphate
Acid Mine Water
Aluminum Hydroxide
Ammonium Chloride
Ammonium Bicarbonate
Ammonium Nitrate
Ammonium Sulphate
Ammonium Phosphate
Asphalt
Asphaltum
Aromatic Hydrocarbons
1. Benzene
2. Benzol
3. Cyclohexane
4. Xylol
5. Xylene
6. Toluene
7. Napthalene
8. Hexane
Barium Chloride
Barium Hydroxide
Barium Nitrate
Barium Sulphate
Beer
Benzene (coal tar product)
Benzine (petroleum product)
Bichloride of Mercury
Beet Sugar Liquor
Beer Wort
Black Liquor
Brine, calciu
Brine, sodiu
Boric Acid
Bordeaux Mix
Boiler Feed W
Carbon Bisulfi
Carbon Tetrachl
Carbon Disulphide
Carbon Dioxide
Carbonic Acid
Carbolic Acid

Calcium Brine
Calcium Chloride
Calcium Acid Sulphate
Calcium Chlorate
Calcium Hypochlorite
Calgon (sodium hexametaphosphate)
Chlorinated Hydrocarbons
1. Carbon Tetrachloride
2. Tri Chloroethyline
3. Ethylene Dichloride
4. Methyl Chloride
5. Propyl Chloride
6. Chloroform
7. Dichloroethylene
Castor Oil
Caustic Potash
Caustic Soda (lye)
Caustic Zinc Chloride
Cellulose Acetate
Cellulose Nitrate
Citric Acid
Clay Slip
Coal Tar Oil
Coal Tar Solvents
Copperas
China Wood Oil
1. Drying Oils
2. Vegetable Oils
Chromic Acid (diluted)
Copper Nitrate
Copper Sulphate
Creosote
Cyanide
Corn
ed Oil
ide of Potassium
Distilled Water or Deionized

Diethylene Glycol (alcohol)
Diethylene Glycol (monoethyl ether)
Distillery Wort
Edible Oils
Epsom Salts
Ethyl Alcohol
Ethyl Acetate
Fatty Acids
Ferric Chloride
Ferric Hydroxide
Ferrous Chloride
Ferrous Sulphate
Formaldehyde
Formic Acid
Fruit Juices
Fuming Sulphuric Acid
Furfural
Fuel Oils
Fusil Oils
Gasoline
Grape Juice
Glue
Glucose
Grain Alcohol
Glycerine
Glyceral
Hydrochloric
Hydrocyanic
Hydrofluosi
Hydrog
ps
Kerosene
Ketones
1. Acetone
2. Ethyl Methyl
3. Methyl Acetone
Lard

Lacquers
Lime Water
Linseed Oil
Lye (Sodium Hydroxide)
Lubricating Oils
Magnesium Chloride
Magnesium Sulphate
Milk of Lime
Mine Water
Mercuric Chloride
Mercury
Molasses
Methanol
Methyl Chlori
Naphtha
Nick
l Sulphate
cid
altum Base
Oil—
Paints
Palmitic Acid
Paraffin (melts at 45° to 60° C.)
Potassium Carbonate
Potassium Chloride

Potassium Cyanide
Potassium Sulphate
Potassium Nitrate
Pickling
Printi
Rosin
Salammoniac
Salt Brine 3%
Salt Brine 3% to 30%
Starch
Sea Water
Sewage
Soap Liquor (thin)
Shellac
Soda
Soy Bean Oil
Sodium Bicarbonate
Sodium Carbonate
Sodium Aluminate

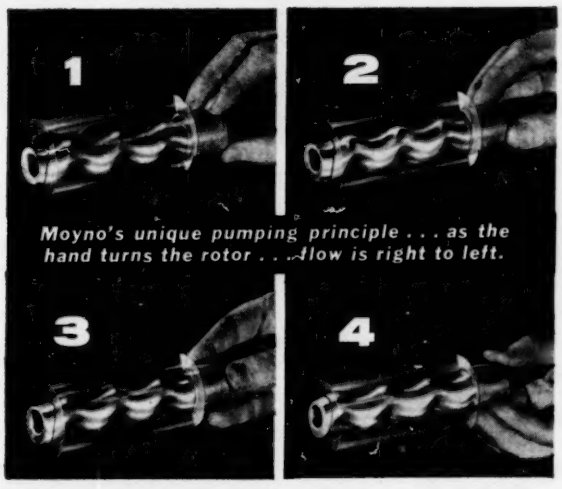
Propane
Rosin
Salammoniac
3% to 30%
Sodium Bisulfite
Sodium Chloride (see salt brine)
Sodium Hydroxide
Sodium Nitrate
Sodium Silicate
Sodium Sulfate
Sulfurous Acid
Sugar
Stearic Acid
Tar
Tar & Ammonia in Water
Turpentine
Toluene (toluol)
Titanium Chloride
Urine
Varnish
Vinegar
Vegetable Oil
Vitriol—Blue
Vitriol—Green
Whiskey
Wine
Wood Pulp
Xylene
Yeast
Zinc Chloride
Zinc Sulfate
Zinc Nitrate

R&M®

MOYNO®
CHEMICAL PUMPS

Abrasives, corrosives or suspended solids...a MOYNO® *will pump it!*

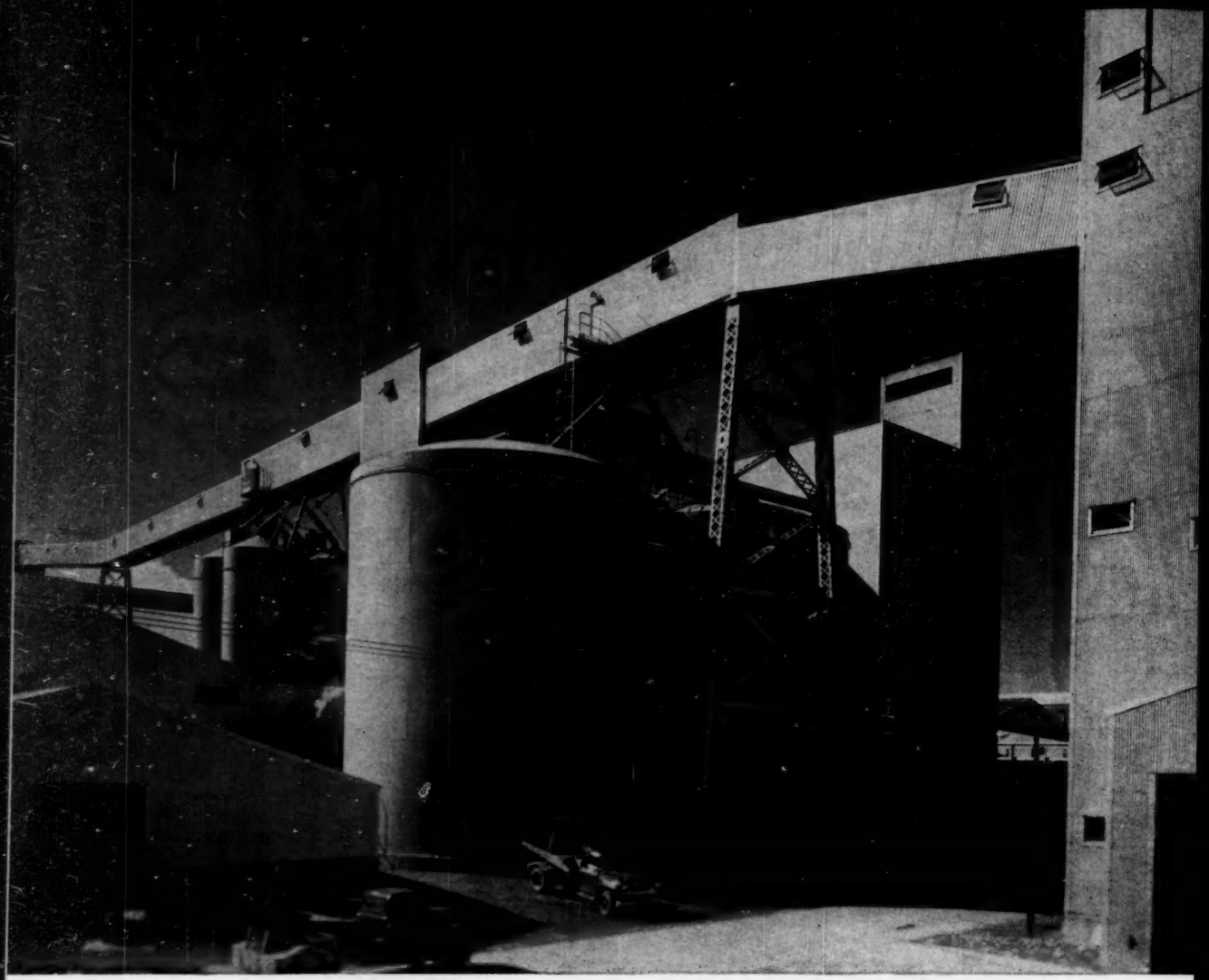
Moyno pumps are successfully handling all the substances listed above, and many others. Makes no difference whether these are thin watery slurries, non-pourable abrasives, gnawing corrosives or suspended particles up to 1⅛" dia.—Moyno will pump it! The wide range of specially-resistant materials in which Moyno pumping elements are available assures exact job-tailored design for economical handling without excessive pump wear. Moyno's single rotating part provides positive displacement . . . delivers uniform discharge without pulsation, agitation or turbulence. Moynos are available in nine sizes with capacities from 1/100 to 500 gpm and pressures up to 1000 psi. Let Moyno cut your pumping costs! See product information in *Chemical Engineering Catalog* or write today for new Bulletin 100-CE!



Moyno's unique pumping principle . . . as the hand turns the rotor . . . flow is right to left.

ROBBINS & MYERS, INC., Springfield, Ohio

Fractional and Integral HP Electric Motors • Electric Hoists and Overhead Traveling Cranes • Moyno® Industrial Pumps
Propellair® Industrial Fans • R & M-Hunter Fans and Electric Heat • Trade-Wind Range Hoods and Ventilators
Subsidiary companies at: Memphis, Tenn., Pico Rivera, Calif., Brantford, Ontario.



Low maintenance...almost no maintenance!
Structurals of REYNOLDS ALUMINUM

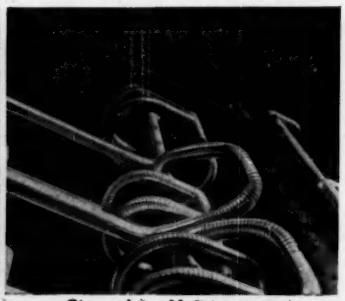
Plant upkeep is cut *substantially* with structurals and equipment of Reynolds Aluminum. Aluminum resists corrosion and weathering, even in the worst industrial atmospheres; it keeps its strength; it won't rust. Seldom, if ever, do you have to provide protective maintenance for aluminum buildings, fences, gratings, structurals, or equipment.

Thanks to the lightweight strength of aluminum, you can speed installation, reduce fabricating, shipping, handling, and erection costs. Aluminum requires less support, and it's non-sparking. For complete literature file, call your local Reynolds office or write *Reynolds Metals Company, P.O. Box 2346-CJ, Richmond 18, Virginia.*

REYNOLDS ALUMINUM FOR CHEMICAL PROCESSING

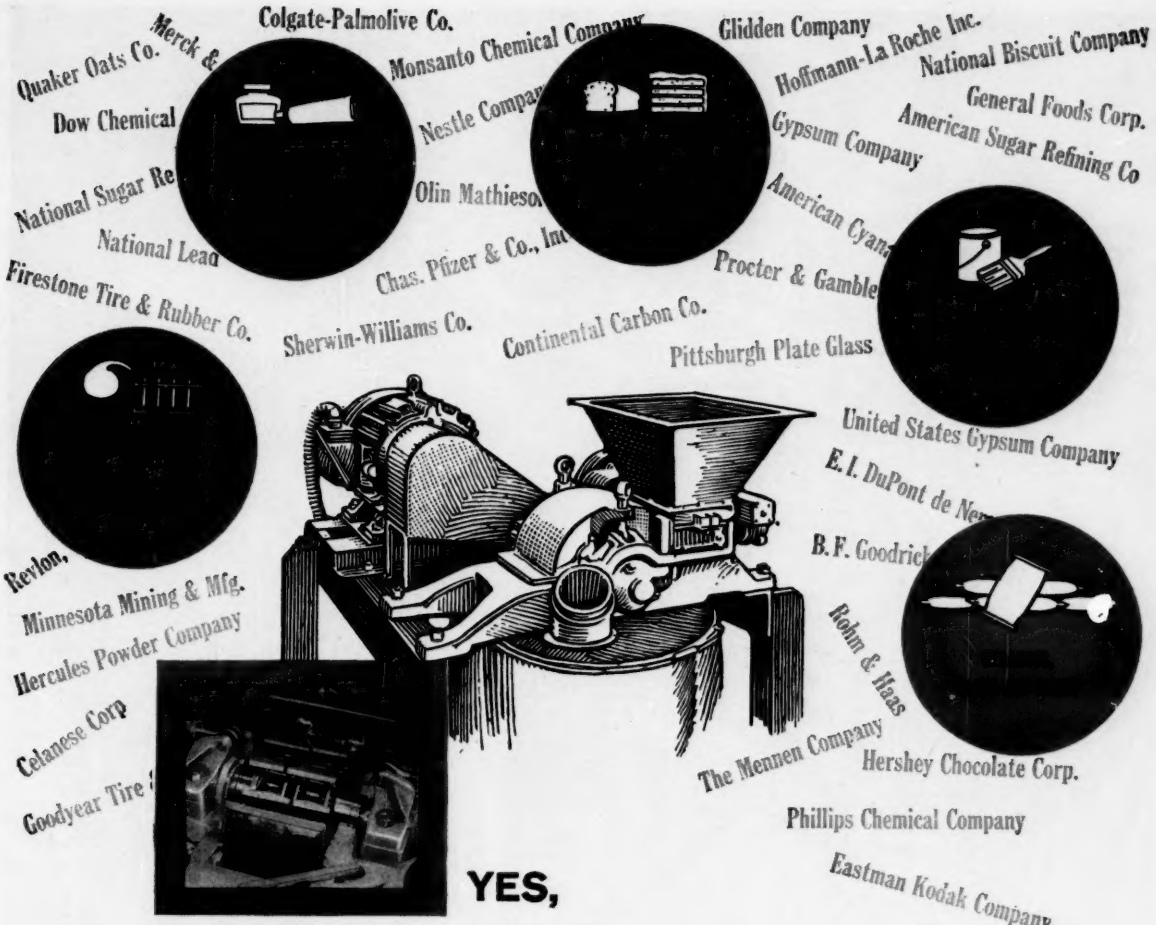
Low-Maintenance Tanks and Vessels

Low-Cost, Corrosion Resistant Process Pipe



Clean, Low-Maintenance Jacketing

Watch Reynolds TV show "Harrigan & Son", Fridays—ABC-TV



YES,

WE ARE

NAME DROPPERS!

Because we are proud of the customers who use MIKRO-PULVERIZERS . . .

In the montage of names that form the background of this ad you will find just a sampling from our published list of prominent MIKRO-PRODUCT users in the process industries. They represent companies of all sizes . . . all equally prized.

Each of these MIKRO-PULVERIZER owners operates a unit with a distinct individuality . . . an internal mechanism adjusted to handle a particular job either in dry-grinding or wet milling.

If you want to know what a job-designed MIKRO-PULVERIZER has to offer you in the way of fine or ultra-fine grinding, precise particle size control, and economy of power and maintenance, write for Bulletin 51A.

MIKRO-Products

PULVERIZING MACHINERY COMPANY

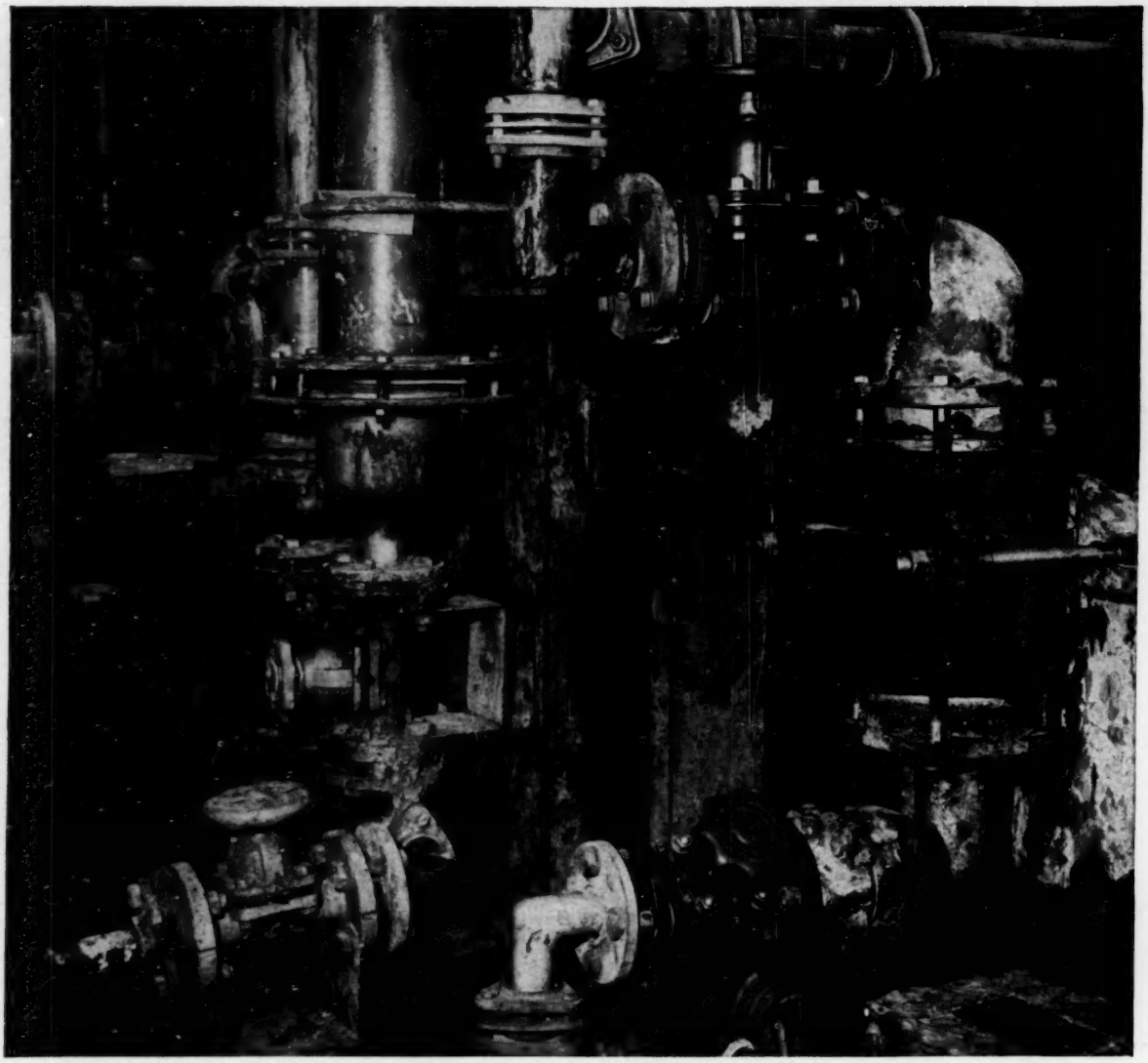
55 Chatham Rd., Summit, N. J.

A Division of American-Marietta Company

PROCESSING SYSTEMS

GRINDING CONVEYING COLLECTING

REPRESENTED THROUGHOUT THE WORLD IN SALES, SERVICE AND MANUFACTURING FACILITIES.



Encrustation on two of the above valves was cleaned off to show lack of external corrosion. Compare this with the corroded condition of the structural steel.

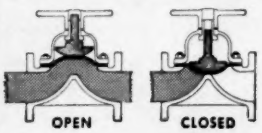
Grinnell-Saunders Diaphragm Valves resist attack by hot corrosives at Carborundum Metals Company

During the past few years, Carborundum Metals Company, a Division of the Carborundum Company, has installed over 200 Grinnell-Saunders Diaphragm Valves at their Parkersburg plant in West Virginia. These valves were coated internally and externally with Penton * —and were equipped with fluorinated plastic diaphragms, backed with elastomer cushions. Their job: to handle highly corrosive caustic soda and sodium hypochlorite–at 212°F, and methyl isobutyl ketone, hydrochloric acid, sulphuric acid at 130°F–all used in processing zirconium ore for zirconium and its co-product, Hafnium.

Today, this manufacturer reports that after being in operation an average of two years, the rugged Grinnell-Saunders Diaphragm Valves are still giving good service. What's more, they've never had to replace parts in these Grinnell Valves!

In Grinnell-Saunders Valves, the diaphragm lifts high for streamline flow – seals *tight* for positive closure. Working mechanism is completely isolated from material in the line to prevent corrosion and contamination. There's a wide choice of body, lining and diaphragm materials, too. See how Grinnell-Saunders Diaphragm Valves can help *your* installation.

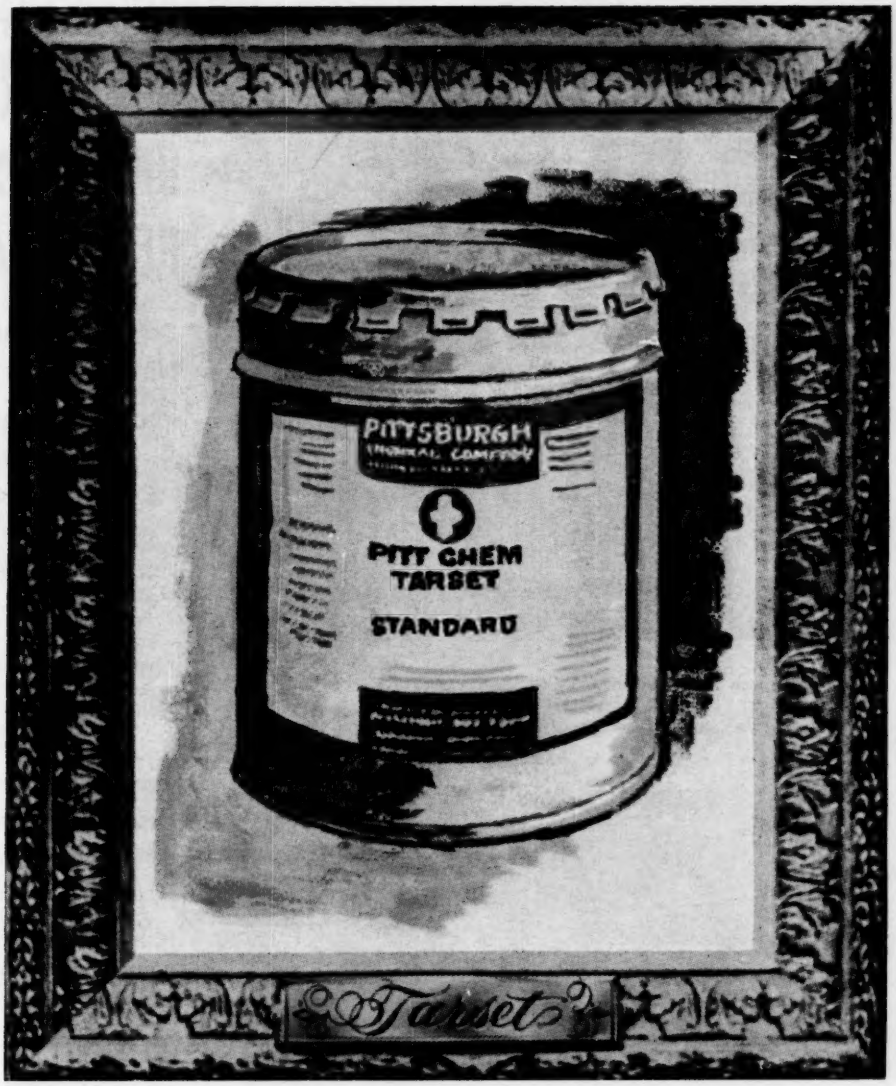
Write Grinnell Company, Providence 1, Rhode Island.



* *Reg. T.M., Hercules Powder Co.*

GRINNELL

GRINNELL COMPANY, PROVIDENCE 1, R. I. • BRANCH WAREHOUSES AND DISTRIBUTORS FROM COAST TO COAST
PIPE FITTINGS • VALVES • PIPE HANGERS • PREFABRICATED PIPING • UNIT HEATERS • PIPING SPECIALTIES



Like any original . . . it cannot be duplicated!

Regardless of claims, *there's only one* TARSET® . . . the *original* coal tar-epoxy resin coating. No other coal tar-epoxy resin coating duplicates the TARSET formula, and it has not been made available to any other coating manufacturer. No other coal tar-epoxy coating combines the proven adhesion characteristics, chemical resistance and low moisture absorption properties of coal tar pitch with the hardness, ruggedness and chemical resistance characteristics of epoxy resins, like Pitt Chem TARSET.

Here are a few advantages of TARSET over other coatings of its type:

1. **Only TARSET is backed with a six-year service record.**
2. **Only TARSET has established so outstanding a performance record.**
3. **Only TARSET is approved by governmental and industrial agencies.**

If you have a corrosion problem that seems unsolvable, investigate TARSET's proven advantages. Contact your nearest Pitt Chem Industrial Distributor . . . he's listed in the "Yellow Pages."

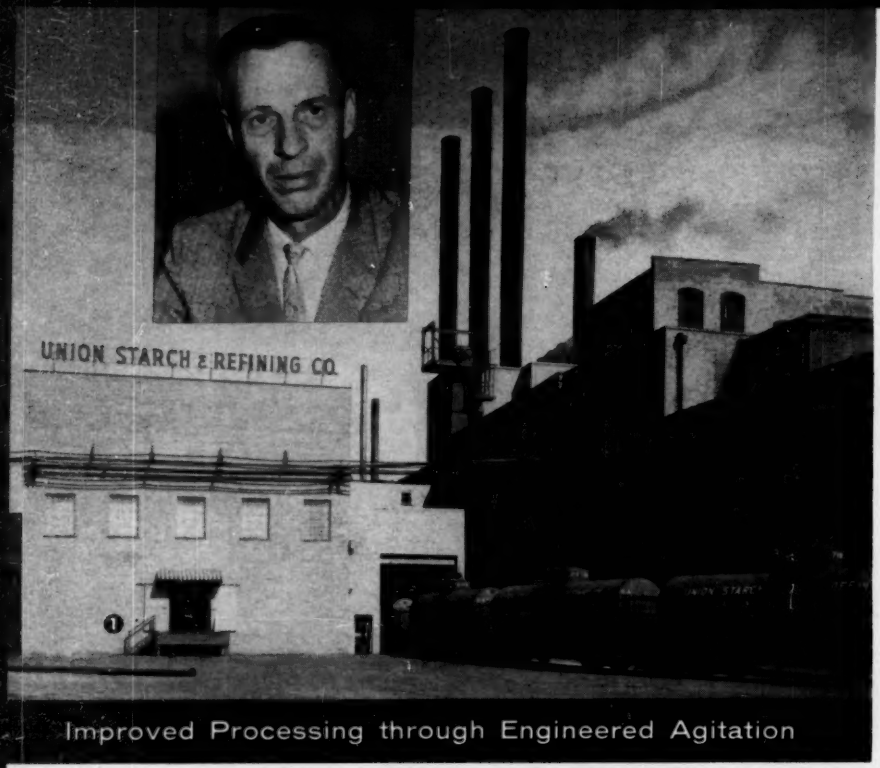
3279

PROTECTIVE COATINGS DIVISION

PITTSBURGH CHEMICAL CO.

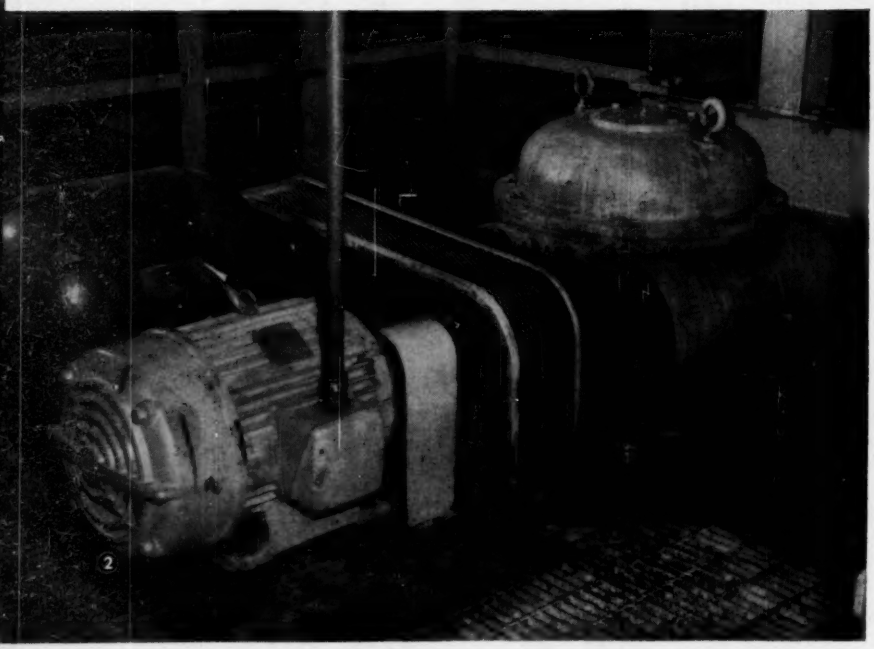
GRANT BUILDING PITTSBURGH 19, PA.

A Subsidiary of PITTSBURGH COKE & CHEMICAL CO.



Improved Processing through Engineered Agitation

1. Union Starch & Refining Co., Granite City, Ill.
2. Nettco Tank Top Agitator with two 25 hp motors, one operating — one as spare.



ADD STARCH AND STIR... UNION'S BIG RECIPE PAYS OFF!

Nettco Solves Suspension Problem for Union Starch and Refining Co.

PROBLEM:

Keeping a huge tank inventory of 192,000 gallons of starch liquor in constant suspension to satisfy a continuous demand 24 hours per day, 7 days per week.

SOLUTION:

Nettco engineers working closely with B. J. Hunter, director of manufacturing determined the exact agitation requirement to maintain contents in uniform suspension at minimum cost. By drawing on years of specialized agitation experience, Nettco was able to utilize one of its standard tank top units — a 40 foot shaft, precision engineered to eliminate whip — and the right type and size of impeller for minimum horsepower.

RESULT:

Rugged, dependable agitation at low initial and operating cost. Repayment of original investment in tank and agitator in one year.

Try the pay-off combination of Nettco standard components, engineering and imagination on your next mixing job. See Chemical Engineering Catalog for nearest representative or request Bulletin 581, Nettco Corporation, 87 Tileston St., Everett 49, Mass.

NETTCO

ENGINEERED AGITATION SPECIALISTS

EVERETT 49, MASSACHUSETTS

Full Flow–Self Lubricating
CHEMTROL BALL VALVE
...in non-corrosive plastics

½" THRU 4" BALL VALVE
Socket-Threaded-Flanged

TEFLON BALL SEAT (Self-lubricating)

PVC I

Basic polyvinyl chloride with excellent chemical resistance...a time proven plastic.

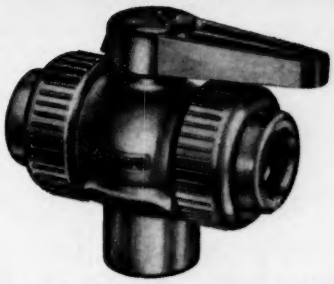
PVC II

Higher in impact strength than PVC I but slightly less resistant to some chemicals.

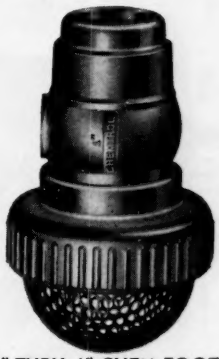
PENTON

High operating temperature limit with an extremely wide range of chemical resistance.

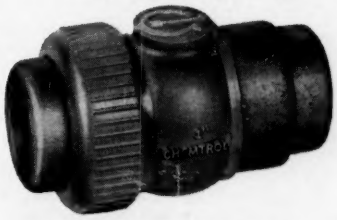
ABS (Acrylonitrile Butadine Styrene) and Polypropylene also available on request.



½"-¾"-1" 3-WAY VALVE
Socket-Threaded-Flanged



½" THRU 4" CHEM-FOOT VALVE
Socket-Threaded-Flanged



½" THRU 4" CHEM-CHECK VALVE
Socket-Threaded-Flanged

In addition to the above, Chemtrol offers a wide range of Needle, Globe, and Cock Valves. Each can be supplied in materials to perform under most chemical resistance requirements.

Newly added to the widest range of Plastic Valves...

THE CHEMTROL OPERATOR VALVE

Now the full-flow CHEMTROL Ball Valve, can be actuated remotely by PVC piston within a PVC cylinder. Air or hydraulics may be employed to move the piston. Automatic operation can be provided through the use of a solenoid valve.

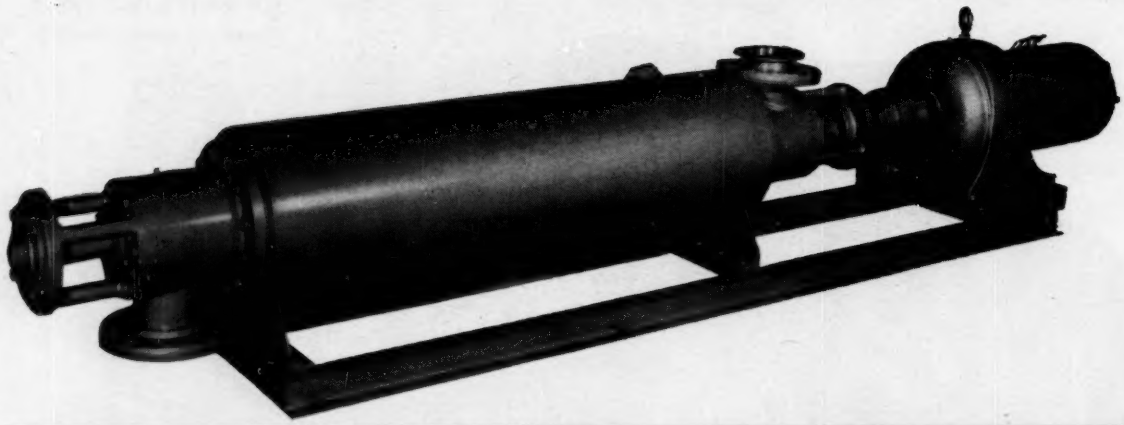
Operation from full-open to full-closed is accomplished in one-half second, providing instantaneous control. In areas where a remote controlled valve is desired, especially in corrosive environment—the new Chemtrol Operator is your answer. For complete information on Chemtrol valves, please write...

KRALOY / CHEMTROL CO., Industrial Division
402 W. Central Avenue, Santa Ana, California

QUALITY PLASTIC PRODUCTS FOR INDUSTRY

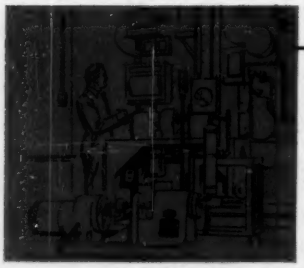
KRALOY/CHEMTROL CO.
SANTA ANA — PHILADELPHIA — DALLAS

PROFITS CAN BE INCREASED



VOTATOR Reactors, supplied for liquid or vapor jacket media, in various metals and designs, and in sizes to suit thruput needs, have high mixing efficiency with good rate of heat transfer. These units feature:

- Working pressures to 500 psi.
- Working temperatures to 750° F.
- Multi-port injection of reactants.
- Low resident time.
- Low pressure drop.
- ASME Coded.



FOR . . .

HEATING
COOLING
EMULSIFYING
MIXING
AERATING
EXTRUDING
SUPER COOLING—FLAKING
POLYMERIZATION
SULFONATION
OXIDATION
SULFATION
NITRATION
SAPONIFICATION
NEUTRALIZATION
CONDENSATION

Continuous processing has become a basic necessity in the rapidly expanding chemical industry. In fact, without it, the cost cutting benefits of increased production are practically impossible. The specially developed VOTATOR Continuous Processing Equipment has been the way to increased production, to lower costs, to improved product quality, *to better profits.*

Designed for controlling many highly exothermic reactions, the VOTATOR Continuous Reactor is one of the most efficient heat transfer mechanisms known. It permits handling of those reactions which evolve considerable quantities of heat as well as those end products which are exceedingly viscous or result in a product which fouls a conventional heat exchange surface.

The ability of VOTATOR Continuous Process Equipment and Systems to step up quality and profits is the result of unmatched experience through many years of direct application . . . and you can put this practical experience to work in solving *your* problems. Get the whole story. Write today for Bulletin V250-F-12. Girdler Process Equipment Division, Chemetron Corporation, Louisville 1, Kentucky. Sales Offices: Louisville, New York, Chicago, Marietta (Georgia), San Francisco.

Votator®

a Product of CHEMETRON *Corporation*

VOTATOR—Reg. U. S. Pat. Off.

Long-lasting Du Pont Armalon® felt resists harsh chemicals... cuts gasket replacement costs ...reduces downtime

When the job for gaskets calls for exposure to harsh chemicals and temperatures ranging from −100° to +600°F., you need a material that can take punishment in its stride. Du Pont's Armalon* TFE fluorocarbon resin-impregnated felt gives gaskets extended life under extreme operating conditions.

It resists attack by strong acids . . . conforms to uneven flanges . . . provides secure sealing at minimum pressures . . . has high anti-stick properties and low coefficient of friction.

Gaskets of "Armalon" last up to 700% longer than those of ordinary materials . . . cut replacement costs. They resist 99.3% sulfuric acid at 200° C. and often remain in service for a year and a half . . . reduce downtime. Stainless-steel pipes with gaskets of "Armalon" have carried HNO_3 fumes at 170°C. with 97 psi for 7 months with no default in operation.

There are scores of examples showing how "Armalon" proves its performance record under the most exacting conditions. A booklet describing many of these will be sent on request. Mail coupon today.

*"Armalon" is Du Pont's registered trademark for its TFE fluorocarbon resin-impregnated felts.

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DU PONT
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BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

E. I. du Pont de Nemours & Co. (Inc.)
Fabrics Division, Dept. CE-1-6, Wilmington 98, Delaware

Please send me free copy of "Armalon" booklet describing gasketing under extreme condiitons.

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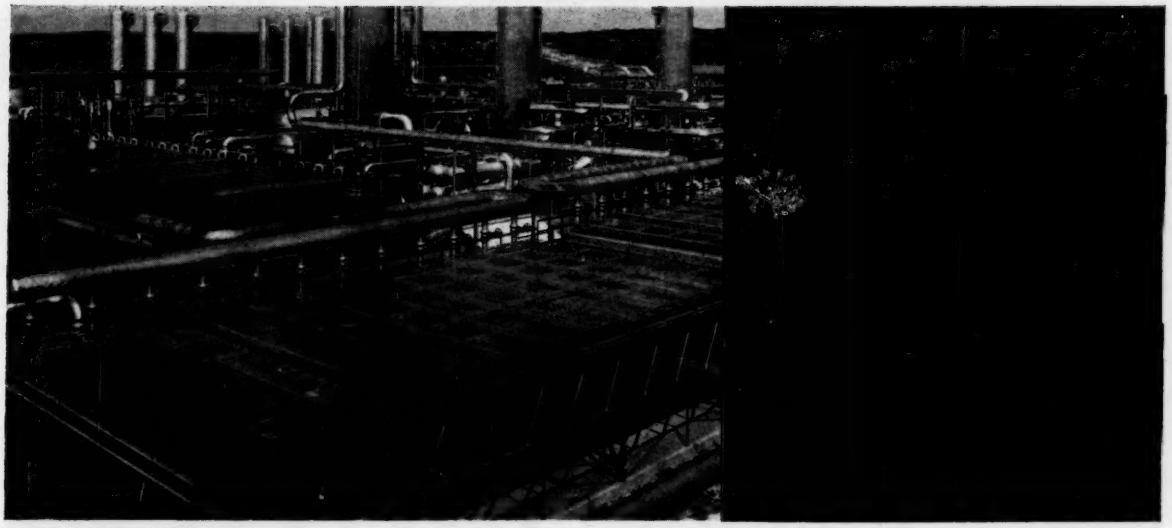
CFC filter uses in the chemical industry range all the way from Alcohol to Xylene. At one leading plant CFC equipment is filtering 400 different organic chemicals; at another cryogenic fluids; at still another CFC filters are wax dehazing lubricating oil. Whatever the chemical application, CFC has the *right* filter.

CFC filters are the choice of the chemical industry because they have been proven under diversified and critical operating conditions . . . because CFC has 25 years of design engineering experience in the chemical field . . . in short because the industry can be sure that a CFC filter is the best filter available, at the lowest cost.

CFC

COMMERCIAL FILTERS CORPORATION
MELROSE 76, MASSACHUSETTS
PLANTS IN MELROSE, MASSACHUSETTS AND LEBANON, INDIANA

IT'S CHEAPER TO KILL HEAT WITH AIR



COMPARE TRANSAIRE . . . no matter what your water situation. Transaire air-cooled heat exchangers already have found wide acceptance in areas where water cooling is impractical or impossible. And now, finding that Transaire is less expensive to operate, even where water is plentiful, other areas are turning to this economical unit.

Simple in basic design, Transaire units are being used in many varied operations where low maintenance and low operating costs are important over extended periods of time. The high heat transfer efficiency is attained by use of the Yuba fintube. Its exclusive design employs tapered spiral fins mechanically bonded so that the entire base tube is covered and protected against the galvanic action that destroys efficiency in many other types of fintube. Both fins and base tubing can be provided in almost any material, size or gauge desired. Fin spacing and height can be varied to requirements. It's cheaper to kill heat with air – next time compare Transaire, a product of Yuba, pioneers in air-cooled heat exchangers.

Yuba also manufactures a complete line of shell and tube heat exchangers, and will recommend either type, whichever is required or best suited for the job.

YUBA

specialists in heat transfer equipment

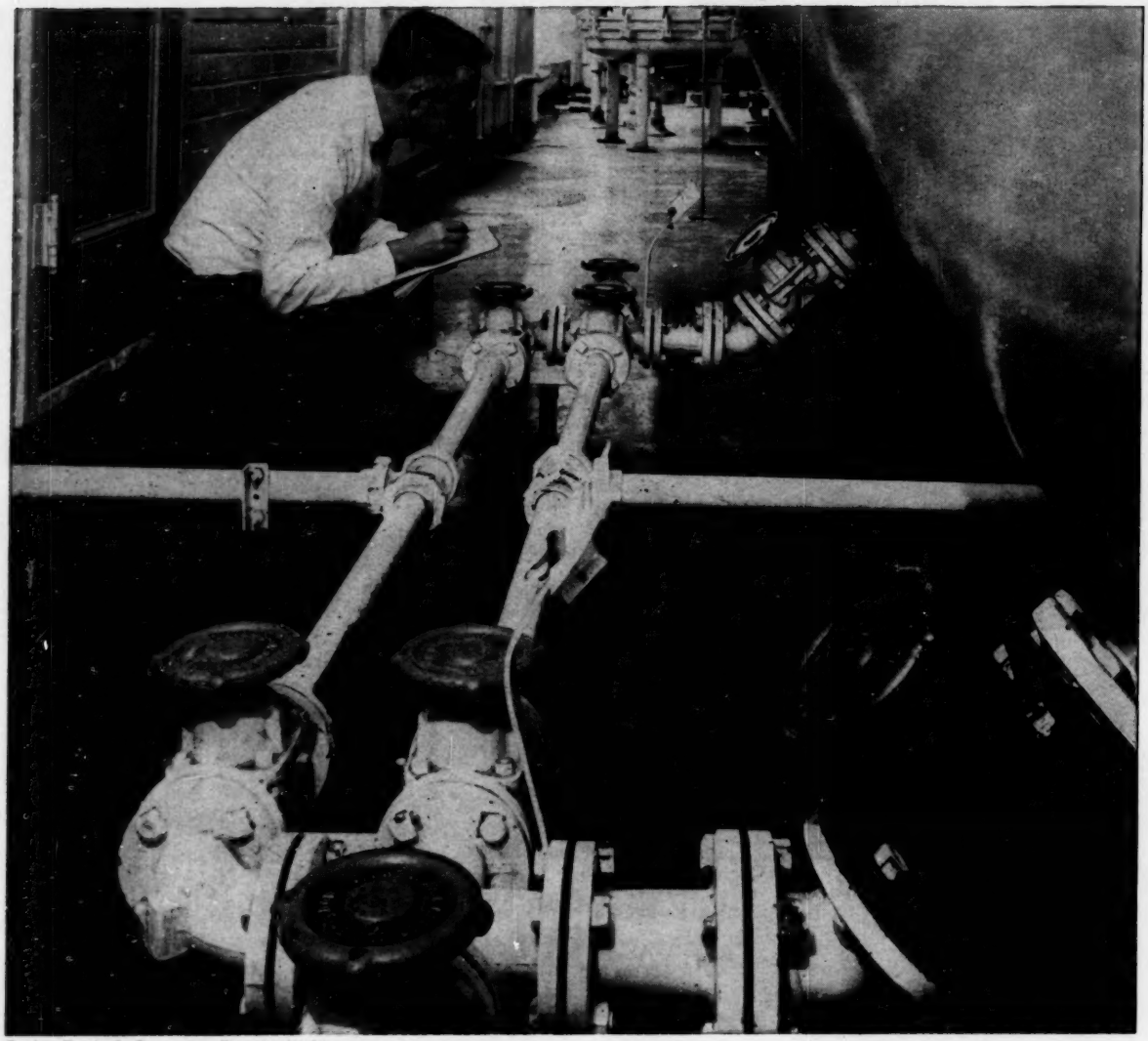
YUBA HEAT TRANSFER CORPORATION

Tulsa, Oklahoma

YUBA CONSOLIDATED INDUSTRIES, INC.

Sales Offices in Chicago • Houston • Los Angeles • New York • Pittsburgh • San Francisco

INTERNATIONAL LICENSEE: Birwelco Ltd., Birmingham, England (United Kingdom, British Commonwealth).



Parke, Davis & Company, Detroit, Michigan

SARAN LINED PIPE—keeps H_2O_2 prescription-pure

...not one failure in three years!

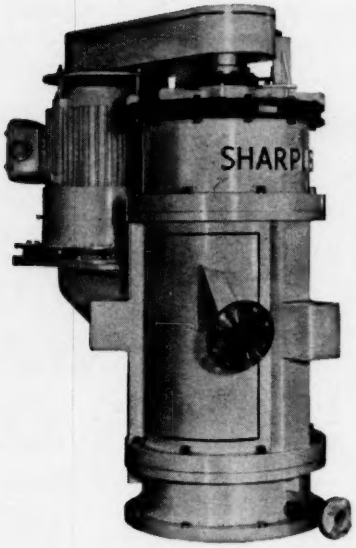
The cargo: 3% pharmaceutical-grade hydrogen peroxide and deionized water . . . carried by a 300-foot pipeline, at floor level near heavy-traffic areas. Pipeline failure would cost $500 per hour in production downtime. Saran Lined Pipe keeps this reactive material prescription-pure, without one case of breakage or failure from corrosion in three years' service!

At Parke, Davis & Company, Detroit, a 300-foot pipeline carries the peroxide solution from dilution tanks to the bottling line. "Three years ago, this line—which used to be ceramic pipe—needed rerouting. At half the cost of dismantling and reassembling the ceramic pipe, we built the new line entirely of Saran Lined Pipe," says Department Manager D. W. Anderson. "The line went up rapidly because its longer pipe sections resulted in fewer joints and its strength eliminated the cost of extra supports."

No matter how corrosive or reactive your chemical material, consider Saran Lined Pipe. Saran Lined Pipe, fittings, valves and pumps are available for systems operating from vacuum to 300 psi, from below zero to 200° F. They can be cut, fitted and modified easily in the field without special equipment. For more information, write Saran Lined Pipe Company, 2415 Burdette Avenue, Ferndale, Michigan, Dept. 1563AK6-12.

THE DOW CHEMICAL COMPANY DOW Midland, Michigan

CENTRIFUGAL SKILL AT WORK



The model P4000 Pressure "D-Canters" have found particular application in the processing of polyolefins.

BROAD-RANGE SOLIDS AND LIQUIDS PROCESSING at Atmospheric OR Pressure Levels

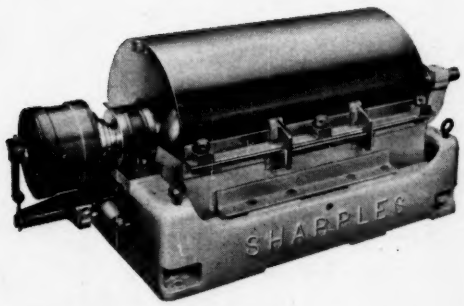
In size, capacity and handling capability, the Sharples Super-D-Canter provides unequalled versatility in processing slurries and suspensions.

For solids dewatering and clarifying—under atmospheric pressure—four horizontal Super-D-Canters are available.

For high pressures or vacuum operation —the vertical Super-D-Canter provides economy processing.

The Super-D-Canter's handling capabilities range from slurries having a solids content of from .05 to 50%, as well as solids from ¼-inch down to a few microns in size.

Write today for more information on the Super-D-Canter and how it can benefit your specific operation.



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THE SHARPLES CORPORATION

Centrifugal and Process Engineers

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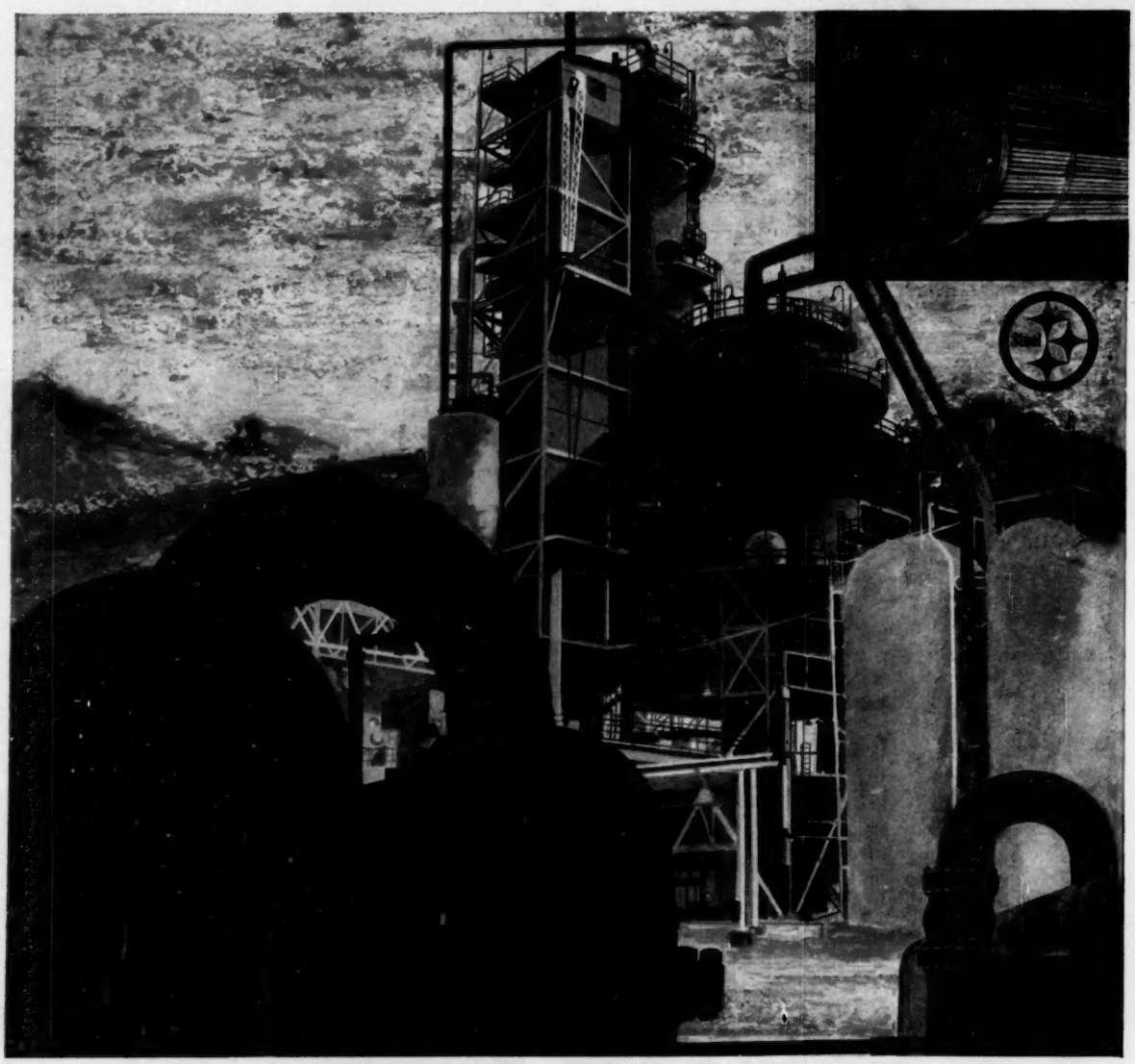
Where does Standard Tube Heat Exchanger Tubing fit into the picture?

EVERYWHERE it is necessary to heat or cool in the modern refinery and processing plant, there are routine and special jobs for welded steel and stainless steel heat exchanger tubing by The Standard Tube Co. Our specialty is heat exchanger tubing. We have the facilities (including hydrostatic and eddy current testing) ... the tube industry's most modern plant. The personnel ... most of our "tubemen" have been with us for years. It all adds up to high quality at lower cost when you specify STANDARD Welded Tubing. Write for brochure No. 5.



Over 40 years specializing in Quality Welded Tubing.

THE STANDARD TUBE CO.

DETROIT 39, MICHIGAN

bone dry

If your plant location is as dry as the sand this Indian is "painting" with, you won't have any caking caustic problems . . . ever. If it isn't, your best move is to buy Wyandotte Flo-chilled® Anhydrous Caustic Soda. This special grade flows readily, even in hot, humid weather—which means you can depend on it every month of the year regardless of your location. Flo-chilling is the difference! You pay no more for Flo-chilled Caustic than for ordinary grades, yet you save money through faster production and less down-time due to caking. Try it now.

Wyandotte Flo-chilled Caustic

MAIL THIS FOR FACTS ON FLO-CHILLED CAUSTIC

ANOTHER WYANDOTTE KEY CHEMICAL

Yes

CUT OUT, FOLD, STAPLE, AND MAIL TODAY!

☐ Send free brochure on Wyandotte Flo-chilled Anhydrous Caustic Soda ☐ data on other anhydrous grades ☐ brochure on economies of 50% vs. 74% liquid caustic. Please include price sheets on ☐ carload quantities ☐ L.C.L. quantities.

I use caustic for_____

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NAME_____

TITLE_____

COMPANY_____

ADDRESS_____

CITY_____ ZONE_____ STATE_____

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MICHIGAN ALKALI DIVISION

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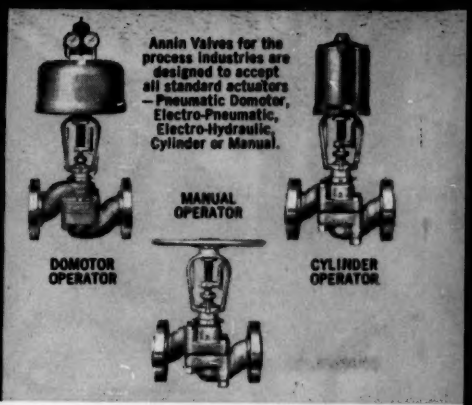
WHY ANNIN IS THE CHEMICAL INDUSTRY'S LEADING PRODUCER OF ALLOY CONTROL VALVES

...OVER $1½ MILLION IN ALLOY VALVE BODY PARTS CARRIED IN STOCK

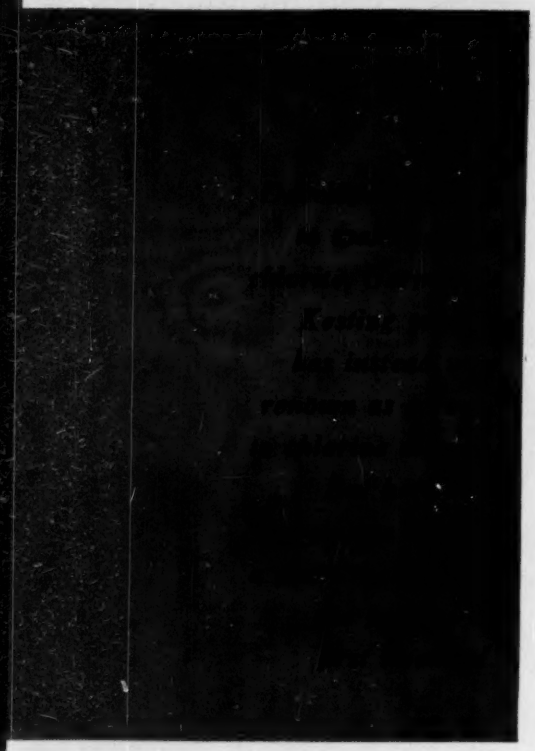

Annin Valves for the process industries are designed to accept all standard actuators — Pneumatic Domotor, Electro-Pneumatic, Electro-Hydraulic, Cylinder or Manual.
MANUAL OPERATOR
DOMOTOR OPERATOR
CYLINDER OPERATOR

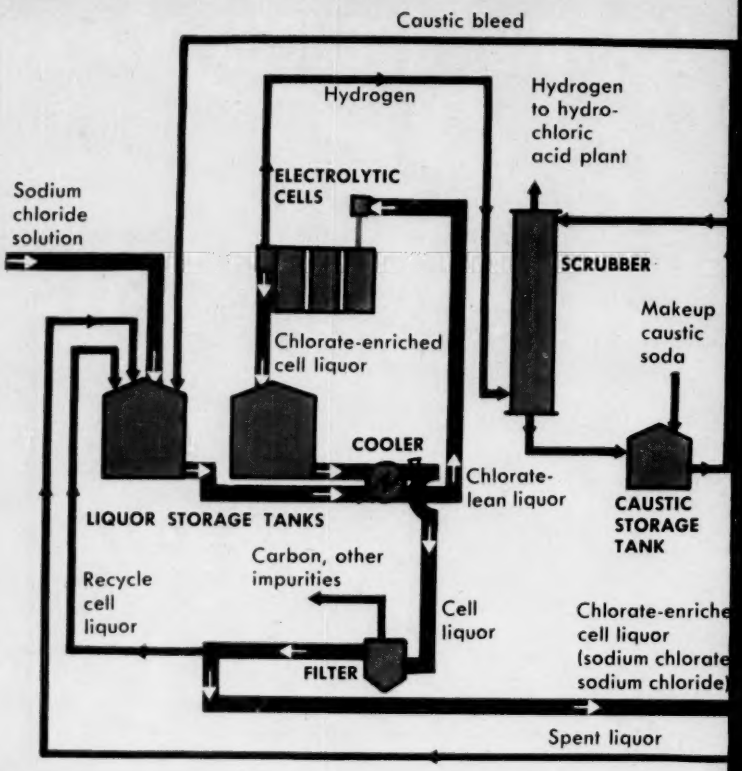
In specifying control valves, the Chemical Industry says make them *strong,* make them *light,* make them *versatile,* and by meeting these standards Annin has become the leading supplier of alloy valves for process control. The above photo, showing a portion of Annin's $1½ million inventory of alloy body parts, is in itself only part of the story. Annin's split body construction... easily replaceable trim... the flexibility of angle, or 3-way bodies immediately supplied from stock... the reduction in overall weight without sacrifice of strength... are other factors in Annin leadership. You can benefit by the inventory economy, ease of maintenance, and basic design advantages of Annin Valves... recognized by control engineers and valve designers as the outstanding valve development of the past twenty-five years for the control of hot, cold, erosive, corrosive, or viscous fluids. *Write today for General Catalog 1500-E.*

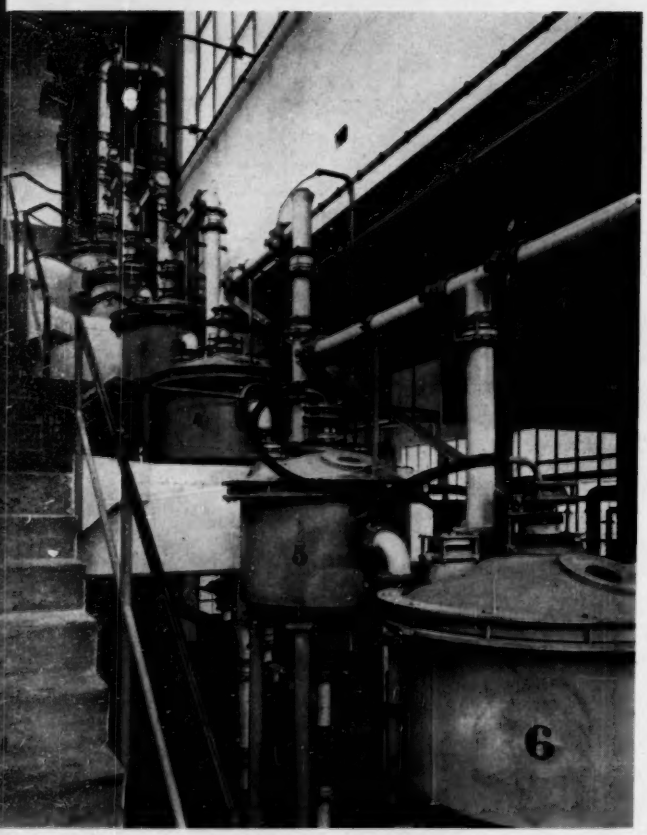
ANNIN VALVES

Products that work for your profit

THE ANNIN COMPANY
1040 So. Vail Ave., Montebello, Calif.



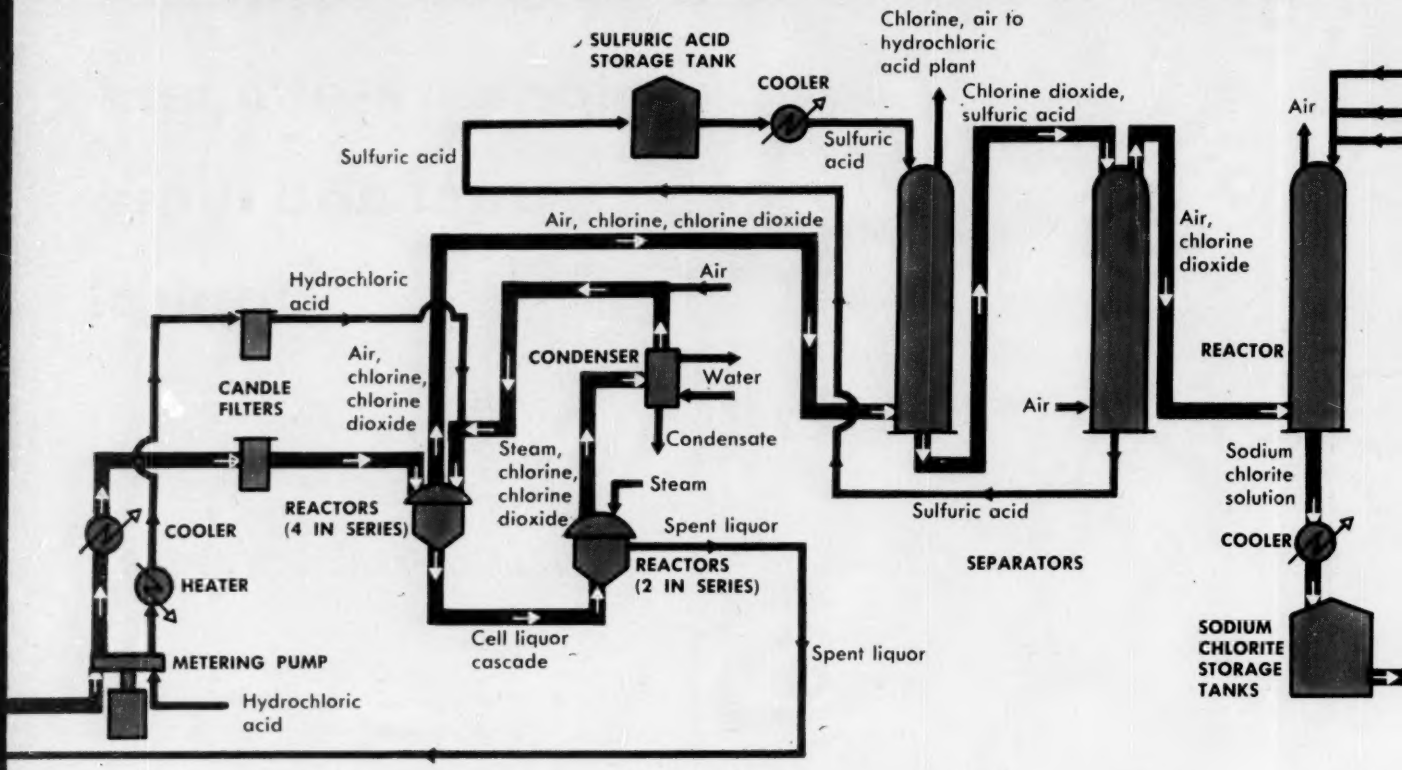




Chlorite Plant Casts Kesting Process in Its Original Role

T. P. FORBATH
McGraw-Hill World News: Bonn, Germany

Cascade arrangement of six reactors houses reaction that produces chlorine dioxide from sodium chlorate.



A process that was developed to make one product, but won worldwide acceptance making another, is now catching on as a route to its original goal.

It's the Kesting process, initially developed by Elektrochemische Werke Muenchen, Munich, Germany, to make sodium chlorite. However, an intermediate product is chlorine dioxide, and engineers quickly noted the virtues of the first half of the German flowsheet for manufacture of the latter material. It is as a route to chlorine dioxide that the Kesting process has made its mark.

But now, at least one firm besides Elektrochemische has decided the over-all flowsheet is likewise highly attractive. The Munich company is on stream with a sodium chlorite plant at that city, and Laporte Chemicals Ltd. is starting up a similar unit at Luton, England.

Sodium chlorite production is highly competitive—in all Europe, there are only seven or eight producers—and accordingly the capacities of the new plants are secret. But, reliable estimates place both between 500 and 1,000 tons/yr.

▶ **Bird's Eye View**—Process consists of three steps: electrolysis converts sodium chloride to sodium chlorate; hydrochloric acid generates chlorine dioxide from the chlorate; then a reaction between the dioxide, caustic soda and hydrogen peroxide yields product chlorite.

Procedure differs in many ways from the more widely used routes to sodium chlorite—for instance, in its use of hydrochloric acid to make chlorine dioxide. But the key departure of both the Munich firm and Laporte is that they produce their own sodium chlorate instead of buying it.

This more than triples the initial plant investment. But Elektrochemische's production manager and Kesting process codeveloper, Hanns Froehler, states that the additional investment is paid for in 2½-3½ years. In the first place, since the process can employ chlorate directly as brine from electrolysis, the Kesting-chlorite manufacturer doesn't pay finishing and shipping costs (and profits) to an outside chlorate supplier. Too, there's no loss of chlorate in Kesting operations, because spent liquor from chlorine dioxide generation recycles to the electrolytic cells.

Another advantage of chlorate production stems from use of hydrochloric acid in making chlorine dioxide. The electrolysis yields byproduct hydrogen, and dioxide production furnishes byproduct chlorine; thus the acid can be produced at the plantsite. Enough chlorine is available to make about half the acid needed.

According to Froehler, these savings permit the Kesting process to make chlorine dioxide for about 8¢ less per pound than do other processes. So, the chlorite is produced comparably cheaper.

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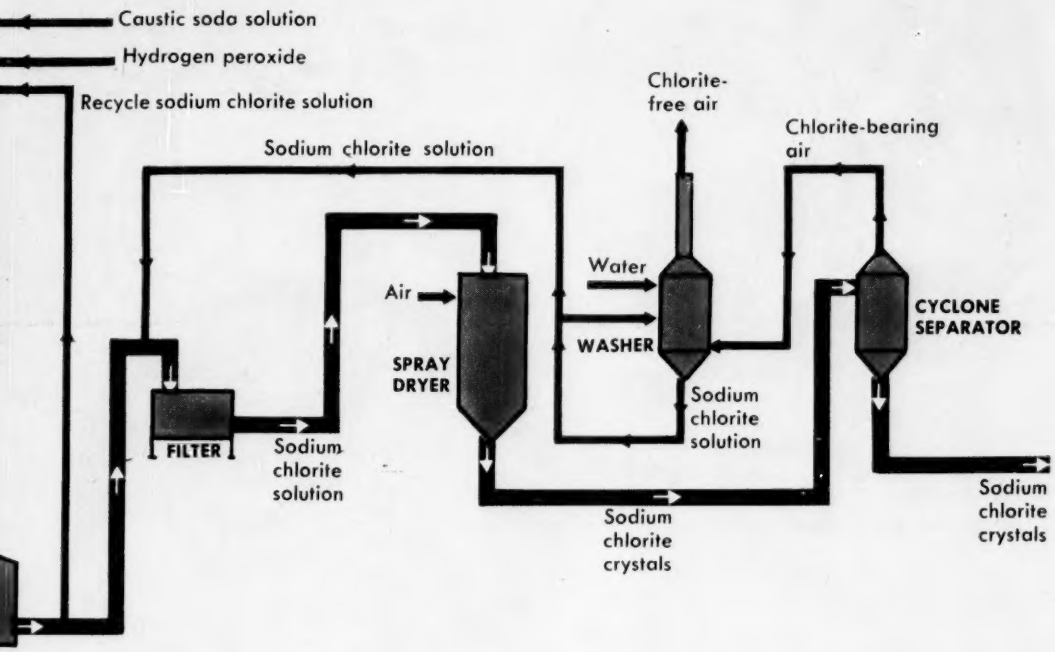

te has forsaken the production of hydro-
d for an even more attractive alterna-
Luton plant uses its byproduct chlorine
dium hypochlorite, a material for which
a large market in Germany. Otherwise,
w plants are essentially the same.
an exclusive tour through the Munich

sis—Fresh sodium chloride solution
circulating system in which an aqueous
sodium chlorate and sodium chloride
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ron storage tanks lined with polyvinyl
nd acid brick, and a water-cooled ti-
t exchanger. Cell feed is at 104 F., has
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nd graphite anodes, operate at 82%
ciency and incur a voltage drop of about
They require 840 amp.-hr. to produce
um chlorate.

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oduct hydrogen. Most of the chlorate-
ell product recycles, but part passes
metering pump, a cooler and a filter to
oxide production.

Dioxide—Filtered cell liquor, about 85
the first of six reactors arranged in
ome of these are made of titanium;
ast iron with titanium lining.

A 30.4% hydrochloric acid solution at about the same temperature also feeds to the first reactor. The mixture cascades through the six vessels, reacting to yield chlorine dioxide, chlorine, water and sodium chloride. A countercurrent gas stream —initially steam, which is then supplemented with air—strips the former two products from the mixture. An undisclosed catalyst minimizes a side reaction that yields no dioxide.

Spent liquor recycles from the last reactor to the electrolysis system. Meanwhile, product gas mixture enters the bottom of a cast-iron separation column lined for corrosion resistance and packed with Raschig rings. Sulfuric acid enters the top around 60 F., descends countercurrently and absorbs the chlorine dioxide.

Chlorine and air leave overhead and go to the hydrochloric acid plant; the acid-dioxide bottoms stream enters the top of a second, similar, column where air strips out the dioxide.

▶ **Sodium Chlorite**—Resulting mixture of air and chlorine dioxide goes to the bottom of a third packed tower, and rises countercurrently to a mixture of hydrogen peroxide, sodium hydroxide and a 60 F. recycle stream of sodium chlorite solution.

Chlorite-enriched solution leaves the bottom of the vessel. Part is recycled; the rest goes to a spray dryer that yields a powder of 80% sodium chlorite, the standard industrial grade.

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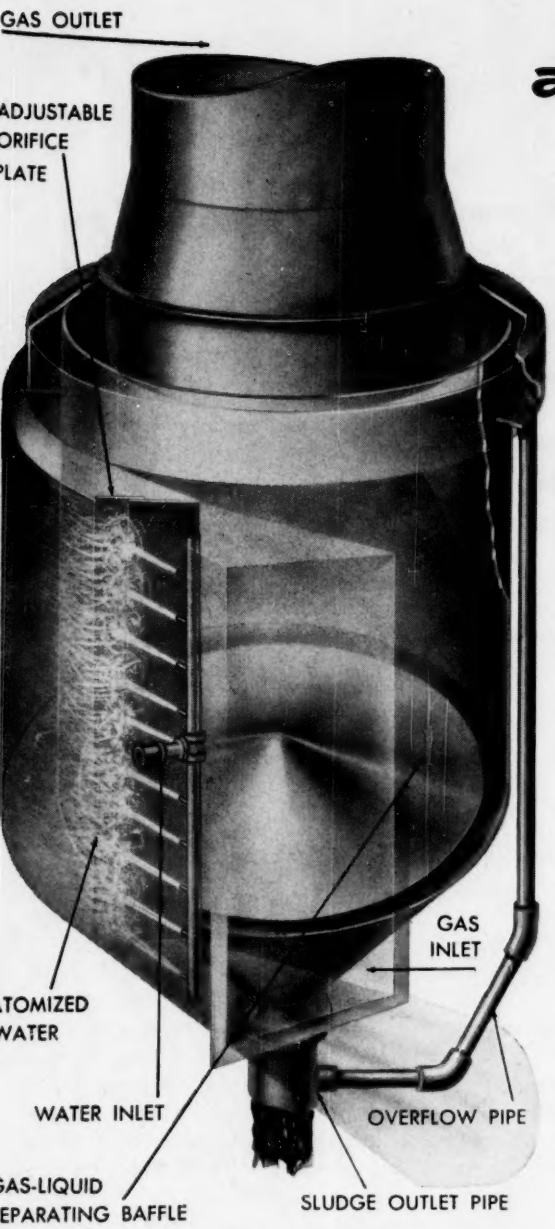

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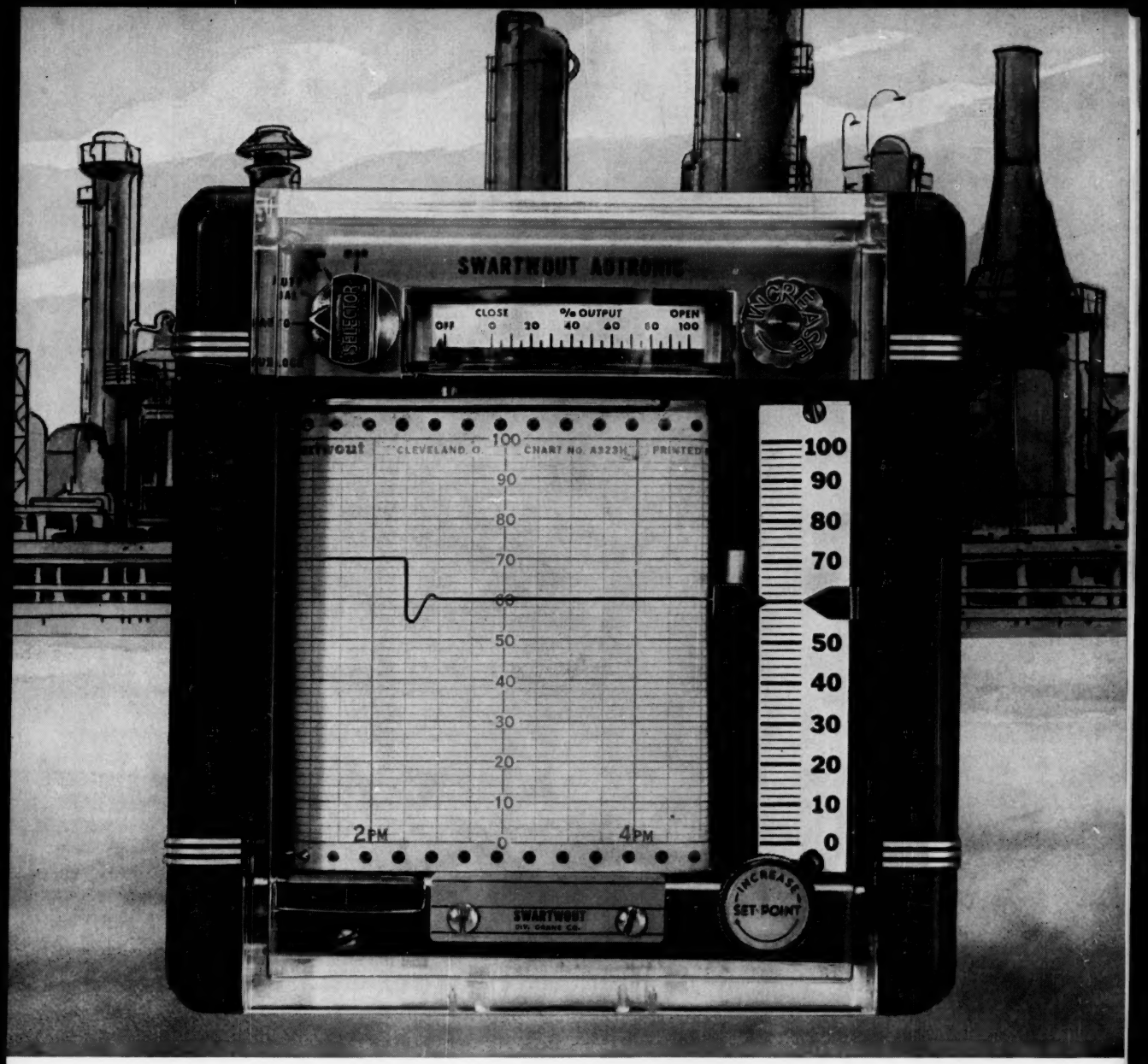

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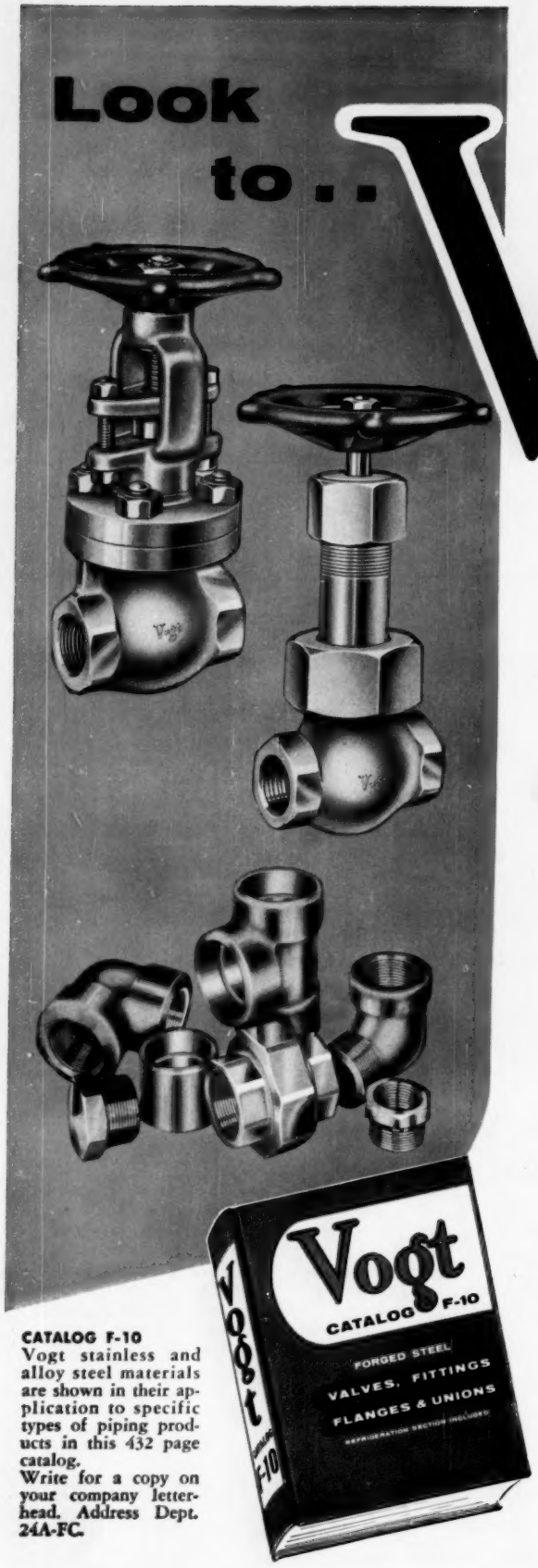

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A CE Feature Report

For the fifth time in a generation, the editors of Chemical Engineering devote a major feature report to chemical process control. The latest, a way-marker on the long path toward better understanding of control principles by chemical engineers, is the first such effort since the magazine began bi-weekly issues in January 1958.

As the magazine has provided the newly useful and retained the proven in other subjects, it has done so in covering control and related areas. With 26 issues each year instead of 12, Chemical Engineering has scanned the field of process control and instrumentation at over twice its former rate, striving to keep chemical engineers up-to-date in the meaning these developments have for them. This report, though, follows a useful format established in 1929: one section of feature articles that explore specific aspects of process control; the other a compendium of instruments, based on their principles of operation.

The growth of control awareness among chemical engineers is reflected in the history of these five reports. Unit operations are old friends to most process engineers, but the process-control loop has become a friend in this generation to many of them. To those for whom process control is a stranger, this report will serve as an introduction. To those who need no introduction, the articles and instrument-elements guide give a wealth of information.

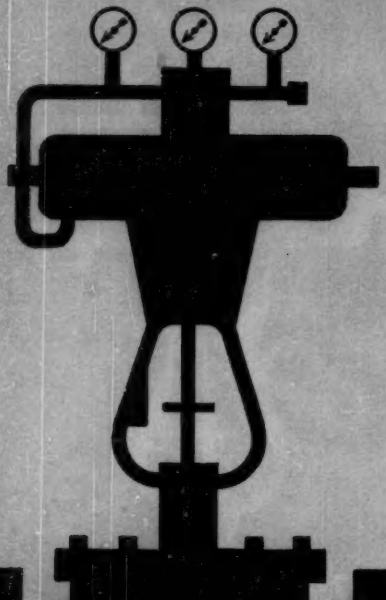
The pattern of the five feature articles is evident in the block diagram of a process-control loop on the next page. Although not attempting comprehensive treatment of the five loop functions shown, the articles do treat in some depth certain important aspects of the functions. In a way, the instrument-elements guide is superposed on the entire loop, for it delineates the hardware that makes process control possible.

The others: April 1929, pp. 193-237; May 1943, pp. 97-111; May 1952, pp. 161-200; June 1957, pp. 249-320.

STEVEN DANATOS WILLIAM C. SCHALL

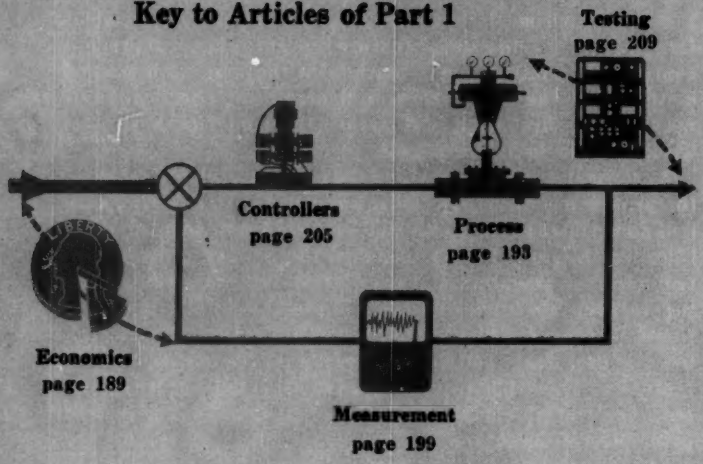
PART 1: Principles
PART 2: Components

PROCESS CONTROL



PART 1: Principles

Key to Articles of Part 1



In the next few years, these will be important:

Computer control. Within the next three to four years, it's likely that the first application of computer control to multiple-process plant operation will be made.

Energy and material-balance control. Why not control what you have to buy and sell? By applying a combination of chemical engineering analysis and control know-how, you can effect great dollar savings.

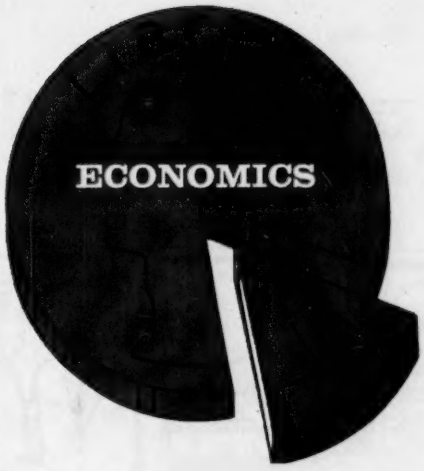
Systems engineering. As more fundamental process understanding is obtained, and techniques and computing equipment become wider-spread, there will be greater acceptance of systems principles in the industry.

Special-purpose controllers. Use of both electronic and pneumatic computing elements will wring out more efficiency in plant operations.

New ways to control. The infused thinking of processing and controlling will lead to new modes of control, and processing.

Easier control application. Greater understanding of control principles, and systemization of application to the standard unit operations and unit processes, will make the task of instrumentation much easier.

Shift of control initiative. Impetus for new control schemes and some devices will shift from the instrument firms to processing companies.



Aware of process economics elsewhere, engineers need to apply it in control.

Dollar-Thinking in Process Control

WILLIAM C. SCHALL, *Associate Editor*

Maybe it's just because control specialists have been able to show spectacular dollar return on many projects. Or maybe it's because the pace of innovation has been too rapid. Whatever the cause, it's always seemed strange that control engineers as a whole haven't adopted economics as a way of thinking. Chemical engineers, used to the "buck balance"—maximization or minimization of dollar values assigned to process variables, have never shied away from the dollar. And they shouldn't do it when it comes to process control.

Control plays an important role in investment in the chemical process industries. According to data on instrument sales compiled by the Dept. of Commerce, the chemical industry accounted for 16.6% of all instrument sales, petroleum accounted for 12.5%, in the period 1947-1957. At the same time, the chemical industry spent only 4%, the petroleum industry only 9.5%, of the total industrial capital expended. This means, on the average, that the chemical industry increases its expenditure on instruments by 4.15% for a 1% increase in total industrial capital expenditure.

The Dept. of Commerce figures also reveal that the ratio of instrument cost to total plant cost ranges from 0.03 to 0.15 for the chemical industry. The all-industry figures here, however, are a little fuzzy from the lack of definition of what "instruments" are. Fortunately, a little better feeling for the cost of instrumentation in the plant can be found. Bach, for example, has prepared cost factors for delivered instruments and their installation in a variety of plant facilities.[1] These factors, useful in ratio estimating are for fluid-processing plants, based on Monsanto Chemical Co. experience.

Another breakdown, which separates batch and continuous processes, correlates instrument cost (% of total direct project cost) vs. total direct project cost.[2] These data, from Dow Chemical Co., show a spread of 5-7% at $8.25 million direct project cost and a spread of 8-11% at $200,000 for continuous-process plants. Haselbarth and Berk have studied some 70 plants in the Gulf Coast processing region, and presented cost ratios which include installed instruments for solids processing, solids-fluid processing and fluid processing.[3] They cover, for each of these three types, two installation sizes (larger than, and smaller than, $10 million) and three ratios (low, average and high).

What Kind of Instruments the CPI Buys

In the last quarter of 1958, Du Pont disclosed the rather awesome figures of its instrument investment.[4] It claimed that 10% of its company-wide plant investment was directly attributable to instrumentation, a value of over $100 million. In 1950, the firm had only $60 million invested in instruments, and in 1933 the control hardware investment was 5% of the total investment.

It should be remembered, too, that the application of advanced control systems is going to up the proportion of investment in instrumentation rather sharply. This is already evident in the application of computer control to chemical processes. The Luling, La., ammonia facility of Monsanto Chemical Co., for example, has cost roughly $20 million. This means that installed instrumentation cost was perhaps $800,000. But when the firm installed computer control last year, it probably cost another $250,000, most of which must be attributed to control hardware and installation.[5] This is a step jump of over 30% in instrument investment.

Importance of Economic Evaluation

These investment figures emphasize the importance of careful economic consideration of control-system proposals. Such consideration requires a fairly solid grasp of how such proposals can be justified. Several

Here's how to apply economics to control

Step 1. Define and collect costs. To make any sense of the costs of past projects, it's necessary to group them by a well-understood code of accounts, keep good records.

Step 2. Look for justification. By finding a number of ways to justify the project, and playing the percentages, return on investment should be made as it's predicted.

writers have tackled this subject,[4, 6-8] so that it shouldn't be a mystery to either management or the engineer.

What are some of the justifications for control systems? It's important to note here not all of them are directly economic reasons. But those that are include:

- Consistent or better-quality product.
- More-economic operation.
- Product sales advantage.
- Making particular process possible.

It is widely recognized in the chemical process industries that justification can rarely be sought in a saving of operating and maintenance labor costs. But some professionals may be displaced by the more-modern control devices. The lab-bench analyst may be replaced by on-line analyzers; a computer or data-logger may assume an engineer's calculations.

There are also justifications for control schemes that lie outside the direct economic sphere. Two examples are safety of operators and equipment, and obedience of the law (e.g., meeting pollution abatement standards). For research purposes, justification may accrue from greater process understanding.

Hazards strew the path of the engineer who must justify a control system. Simply defining the control system is sometimes a tough job, especially when it must be explained to an accountant or manager who is not technically trained.[8]

The Cost of Control Systems

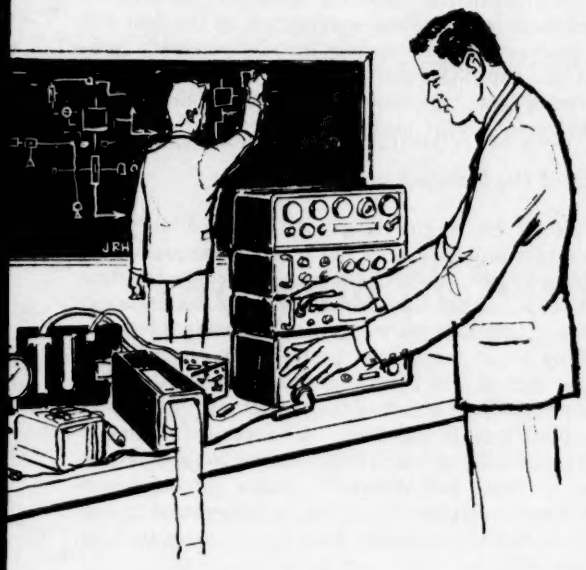
After determining where justification can be made—and it's wise here to exploit all possible reasons to assure the payout—it's necessary to determine costs. For order-of-magnitude estimating, at a preliminary stage of the project, it's possible to use the correlations and ratios cited above. But firm, bid estimates require better data. If systematically kept, cost records from previous projects that are suitably modified for new conditions and cost inflation are one good source. Vendors, too, will furnish detailed estimates of their equipment.

Some detailed instrument costs and how to use them have appeared in the literature.[8,9] In one such summary, a range (low, average, high) is given for purchase cost of each instrument.[10] In all these articles, installation costs are factored with purchase price.

Two helpful articles illustrate the importance of keeping good records in your own operations. Concerned with the costs of pneumatic control systems, the first[11] shows how unit material and labor costs are applied to the estimation of various control schemes. The second[12] presents labor factors for installation of pneumatic instrumentation.

It's been asserted that cost accounting has been losing the fast-paced race with control technology and inflation.[13] The penalized, however, have been those who have been involved in economic analysis of

Step 3. Relate cost and performance. Useful engineering tools are available to assign dollar costs to performance of instrument components or of the process control loops.



Step 4. Compute and measure payout. Both before and after project is installed, it is necessary to see if it meets demanded return. Statistics can help with this problem.

control systems. It's also true, however, that it's not as simple to use the common cost correlation techniques for control equipment as it is for process equipment, which can often, for example, be related to cost by a capacity factor. Some instrumentation costs have been correlated in cost-capacity fashion, e.g., control valves, orifice plates and thermowells.[14]

In two articles, [15, 16] Kalbfleisch presents a cost-estimating method for temperature and pressure control systems. Encompassing the factors of range, desired accuracy, sensing element to be used and type of system, the technique should be extendible to other types of control loops, with only a minimum of effort on the part of engineers who are interested. Other cost-correlation methods have been tried, but none of the following have been published. Since they imply a unit-operations approach to the problem, they should be popular with chemical engineers:

- Cost vs. number of control loops.
- Cost vs. number of loops, with type of loop as a parameter.
- Complexity ratios—base term for main control-equipment item, additional terms to account for various degrees of loop complexity.

Once instrument cost records are compiled and, if possible, correlated by some such method as above, it's possible to use them for order-of-magnitude and preliminary estimating. But the values that are picked off the charts and graphs should probably be modified by factoring with a suitable cost-inflation index. One index for this purpose is Nelson's composite instruments index. The weighting of this index was recently revised for current buying patterns.[17] In addition to the composite index, Nelson also presents indexes for the individual instruments that make it up.

Costs and Performance

After defining and collecting costs of instruments and their installation and maintenance, it's necessary to knuckle down to the cost and economic evaluation of control systems. Just as it is possible to find out whether process equipment meets the specifications that were paid for, techniques have been described to determine the suitability of instruments. Chemical engineers, however, have not generally discovered these cost-performance techniques, as applied to instrumentation.

One rational method for economic evaluation of process control systems or individual instrument components was proposed by Page Buckley of Du Pont.[18] Based on analysis of instruments or of control loops by frequency response, the Buckley technique makes it possible to attach dollars and cents to the spectacular gains that control often offers. A manager might be skeptical of claims of a 2,000% increase in performance, and even if he weren't, he would probably think the cost would be too high. So it's valuable to be able

to assign a cost to the performance, and that is what the Buckley technique makes possible.

Briefly, here's how it works: a performance criterion is established by assuming that component or loop response to a process change affecting control is important. Since the ratio of output signal magnitude to input signal magnitude is ideally 1.0, and since at low frequencies the ratio is 1.0, the falling off of response at higher frequencies marks worsening performance. By setting a particular magnitude ratio as the criterion, it's possible to find out which equipment or which loop arrangements best meet the criterion, and, of course, there is a cost figure associated with the equipment or loop. It is also possible to see how much incremental cost is involved in improvement beyond the goal initially set.

But beyond the problem of quantitatively relating cost and performance of instruments and control systems, it's also often necessary to quantitatively justify the application of instrumentation. This is true in a modernization project, for example, where by the addition of equipment the process efficiency will be improved. Cost of the addition of the equipment, however, must be justified by the payout for it.

When the application of a new control system must be justified by the production increment that accrues from it, a problem arises as to *how* the improvement can actually be determined. Plants are designed to operate at a steady-state point, for example, and the instruments help maintain that point. In measuring production or quality, however, values differ from hour to hour, day to day and season to season. If a control system reduces the excursions from the operating point, it may be money in the bank for the processor. Two papers have appeared that tackle this subject, the second of which presents a chart showing the relationship between oscillation amplitude and percent loss in earnings.[19, 20]

Using Statistics for Cost Studies

From their familiarity with quantitative chemical analysis, at the very least, chemical engineers are used to some rudiments of applying statistics to measurements. Measurement, of course, is also important to control systems and recognition of the possibilities of applying statistics to evaluation of measuring devices has been made by Mahood.[21] Besides facilitating the comparison of instruments for purchase, the techniques of statistics are also extended to compiling information on the maintenance of instruments. The method outlined and illustrated by Mahood does not consider the problem of payout, however.

Perhaps because of the importance of showing return on investment in high-capital computer-control projects, Stout[22] has applied statistics to evaluation of control system payout from process data. The small percentage improvement in operation in these projects may be large in terms of dollars, but it's not easy to sight unless systematic treatment of operating data by statistics is provided.

Stout shows a three-step program for evaluation that includes statistical analysis of operating data before application of the new system, analysis of "operating" data of the optimized mathematical model of the plant, and analysis of the operating data after the control system is applied. Comparison of the first two statistical analyses provides justification before buying the system; comparison of the first and last analyses shows whether installation really provided the hoped-for payout.

Vannah[23] has also considered the application of statistics to payout evaluation.

Proof of the Pudding Is in Payout

With all the engineering tools outlined above, it should be possible to work out a fairly comprehensive program of cost evaluation for process-control instruments and systems. Too, examination of the ideas put forth by these authors will possibly stimulate broader thinking about the special problems of economics in process control. But the final proof demanded in any economic enterprise is that the project meet the return on capital that is expected. A convenient summary of the profitability yardsticks commonly used is provided by Bates and Weaver.[24] And a simplified consideration of percent return due to incremental investment in instrumentation projects is presented by Crawford.[25]

In conclusion, a note of warning: cost isn't the only factor that goes into a purchasing decision, and this is generally recognized by engineers when they purchase the equipment with which they are familiar. But the request for bids and evaluation of bids for control systems is very important, and they have been treated commendably by Bell.[26, 27]

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Valuable process know-how, either from fundamentals or plant experience, is a part of the chemical engineer's repertory. This know-how helps identify the control problem.

Analysis of Fluid-System Dynamics

A. R. PECK, *Polytechnic Institute of Brooklyn*

Ohm's law for an a.c circuit can be written:

$$e = Zi$$

where the impedance Z is a resistance to current flow, due not only to pure resistance but also to inductance and capacitance. These last two quantities cause a phase shift between current and voltage.

We can also use Ohm's law for a fluid system in the form

$$P = ZQ$$

where P is the pressure and Q is the volumetric flow rate (cu.ft./sec.).

Normally, in fluid flow systems, we consider only the steady state, in which there is only frictional resistance, and for which Ohm's law is

$$P = RQ$$

However, for control purposes, the system is not at steady state, and inertia (inductance) and material storage (capacitance) in the system must be taken into account. Now we must use the idea of impedance with a phase angle,

$$P = ZQ$$

or

$$P/Q = Z$$

If we set about deriving the equations for the unsteady state in a fluid-flow system, we get a set of differential equations similar to those we get when we analyze an a.c. transmission circuit.

We can do this in reverse by sketching an a.c. transmission circuit whose describing equations will fit our fluid-flow system. Table I shows electrical circuit elements and their fluid system equivalents.

Consider the system of Fig. 1, which is a compressor and aftercooler delivering a flow of air to a line and a storage tank fitted with an outlet valve. Material storage, or capacitance, is present in the aftercooler, the line and the storage tank. Inertance exists in the line. Friction resistance exists in the line and in the tank outlet valve.

There are two equivalent ways of writing the electrical system for the line, as shown in Fig. 2. We may either divide the line resistance and inductance into two halves on either side of the capacitance (Fig. 2a), or divide the capacitance into two halves on either side of the resistance and inductance (Fig. 2b). The latter usually makes for a simpler circuit.

Fig. 3 shows two equivalent circuits for the compressor system of Fig. 1. Fig. 3b is a simplification of Fig. 3a, in which the capacitances are combined.

$$C_A = (C_L/2) + C_C$$

$$C_B = (C_L/2) + C_T$$

Evaluating the Fluid Circuit Elements

Resistance—Unlike electrical circuit elements, the values of the fluid-circuit elements vary and must be "linearized," that is, evaluated at some operating point and only used in a narrow range.

Skin friction in the line is given by the Fanning equation:

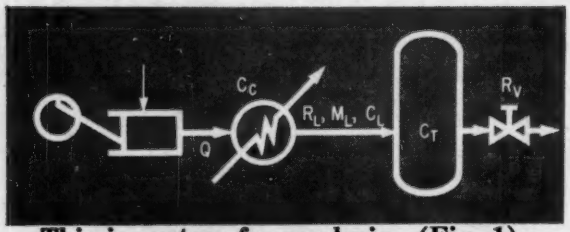
$$\Delta P = 2fl\rho Q^2/gDA^2$$

and the resistance is given by the slope of this curve:

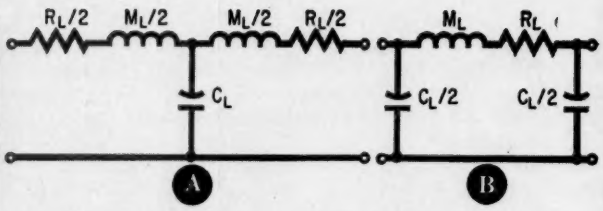
$$P/Q = R = 4fl\rho Q/gDA^2$$

Equivalent fluid and electric elements—Table I

Electrical Symbol	Electrical Element	Units	Fluid Element	Units	Fluid Symbol
e	potential	volts	pressure	lb./sq. ft.	P
i	current	amperes	flow rate	cu. ft./sec.	Q
R	resistance	ohms	friction resistance	lb. sec./ft.^{5}	R
L	inductance	henrys	inertance	lb. sec.^{2}/ft.^{5}	M
C	capacitance	farads	capacitance	ft.^{5}/lb.	C



This is system for analysis—(Fig. 1)



Electrical analogs for line—(Fig. 2)

From this, we see that the resistance varies with the flow rate, and so we must limit ourselves to deviations in flow that do not vary too much from the value chosen for Q at the operating point.

A similar problem arises in estimating R_v, the valve resistance. This depends not only on the flow rate but also on the valve position. Again, we must work at some average flow Q_o, and also at some particular stem position X. Then,

$$\Delta P/Q_o = R_V = KX$$

where K is a proportional constant.

Inertance—Like resistance, the inertance, due to momentum of fluid in the line, must be linearized around an operating point. The inertance is given by:

$$M = \rho l/gA$$

For a liquid, the density is essentially constant, but for a gas, ρ is dependent upon pressure and temperature. In the compressor system of Fig. 1, the density must be evaluated at the average temperature and pressure in the line.

Capacitance—There are three types of capacitance (material storage) that can occur in a fluid system. The volume capacitance for gas is

$$C = V/P \quad \text{(isothermal)}$$
$$C = V/\gamma P \quad \text{(adiabatic)}$$

For fluid compression,

$$C = V/B$$

where B is the "bulk modulus" of the liquid.

The capacitance for line and tank expansion, due to pressure, is essentially

$$C = \left(\frac{\pi D^2 l}{4 Eh}\right)$$

This applies to lines and tanks where the length is large in comparison with the diameter, so that the "stretch" is essentially all in increased pipe diameter.

The Transformed Circuit

At steady state, only the resistance affects the system, but when the system is fluctuating, the reactive elements—inertance and capacitance—come into play. However, the extent to which these elements influence the circuit depends on the rate at which the disturbance is occurring.

Mathematically, this is dealt with by applying the Laplace transform to the differential equations that describe the system. However, if we consider the equivalent circuit of Fig. 2, we can accomplish the same thing by "transforming" the circuit. To do this, we represent the "reactance," or equivalent resistance of the capacitance and inertance, as follows:

$$X_C = 1/Cs$$
$$X_M = Ms$$
$$X_R = R$$

The s is the so-called Laplace operator, and here it takes care of the mathematics that arise from the unsteady state.

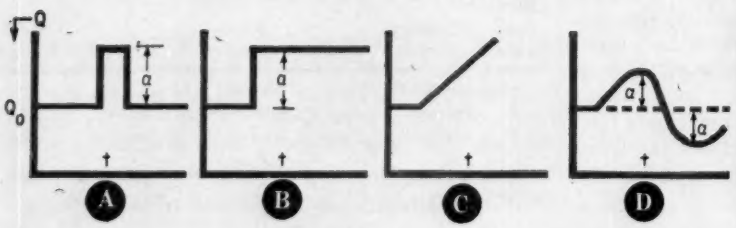
Once we have the transformed circuit, we can combine reactances in the same way we do resistances in a normal circuit. Thus, reactances in series are simply added together, and the equivalent to a parallel arrangement is given by the product of the reactances divided by their sum.

Ohm's law still holds in the transformed circuit, or "s plane":

$$P(s)/Q(s) = Z(s)$$

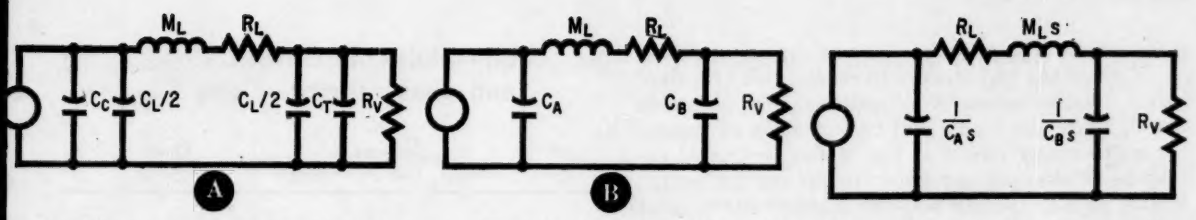
The (s) in parentheses is attached to the various

These are four common time-function inputs—(Fig. 5)



Time-function inputs—Table II

Type	$f(t)$
Impulse	$Q = Q_o + \alpha\Delta t$
Step function	$Q = Q_o + \alpha$
Ramp function	$Q = Q_o + kt$
Sinusoidal	$Q = Q_o + \alpha \sin \omega t$



▲ These are equivalent systems—(Fig. 3) ▲ ▲ This is transformed circuit—(Fig. 4) ▲

quantities to remind us that we are no longer in the normal, or real, variables but are now in the transformed variables.

In Fig. 4, the source (compressor) "sees" the load R_V in parallel with the capacitance C_B:

$$Z_1 = \frac{R_V\,(1/C_B\,s)}{R_V + (1/C_B\,s)} = \frac{R_V}{R_V\,C_B\,s + 1}$$

This impedance, in turn, is in series with R_L and the inertance M_L:

$$Z_2 = Z_1 + R_L + M_L\,s = \frac{R_V + (R_L + M_L\,s)\,(R_V\,C_B + 1)}{R_V\,C_B\,s + 1}$$

And, in turn, the source "sees" Z_2 in parallel with the capacitance C_A:

$$Z = \frac{Z_2\,(1/C_A\,s)}{Z_2 + (1/C_A\,s)} = Z_2/(Z_2\,C_A\,s + 1)$$

$$= \left[\frac{R_V + (R_L + M_L\,s)\,(R_V\,C_B\,s + 1)}{R_V\,C_B\,s + 1}\right] \div \left[\left(\frac{R_V + (R_L + M_L\,s)\,(R_V\,C_B\,s + 1)}{R_V\,C_B\,s + 1}\right) C_A\,s + 1\right]$$

$$Z\,(s) = \frac{R_V + (R_L + M_L\,s)\,(R_V\,C_B\,s + 1)}{[R_V + (R_L + M_L\,s)\,(R_V\,C_B\,s + 1)]\,C_A\,s + R_V\,C_B\,s + 1}$$

$$= [(R_V\,M_L\,C_B)\,s^2 + (R_V\,R_L\,C_B + M_L)\,s + (R_V + R_L)] \div [(R_V\,M_L\,C_A\,C_B)\,s^3 + (R_V\,R_L\,C_A\,C_B + C_A\,M_L)\,s^2 + (C_A\,R_V + C_A\,R_L)\,s + R_V\,C_B\,s + 1]$$

In this development, we have chosen the flow rate Q as the independent variable. The expression we have obtained is the "transfer function" $G(s)$ for the system, where

$$G = \text{output/input} = \Delta P/Q$$

If we had chosen the pressure as the independent, or input, variable, Ohm's law would have been written in the form:

$$Q = Y\Delta P$$

where Y is the admittance (the dynamic equivalent of conductance). The circuit elements would then be combined as conductances.

In parallel: $Y = X_1 + X_2 + X_3 + \ldots$

In series: $Y = X_1\,X_2\,X_3 \ldots /(X_1 + X_2 + X_3 + \ldots)$

In transfer function form:

$$\frac{Q\,(s)}{\Delta P\,(s)} = Y\,(s) = \text{output/input}$$

It is important to specify the independent (input) variable and dependent (output) variable at the beginning of the analysis, and then to write the final expression in transfer function form (output/input), since this expression is actually the differential equation of the system with respect to time, in the Laplace transform or "s domain," subject to the following assumptions:

1. The input variable is a known function of time.

$$Q = f\,(t)$$

or

$$\Delta P = f\,(t)$$

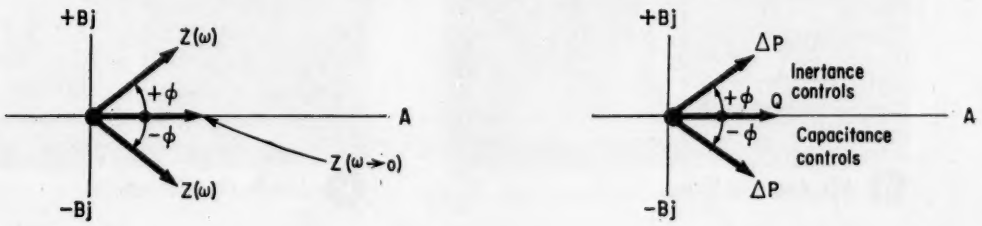
2. At time $t = 0$, all derivatives with respect to time are zero, i.e., initial boundary conditions are all zero.

3. The disturbances in Q and ΔP are sufficiently small so as to maintain reasonably constant the linearized values of resistance, inertance and capacitance.

Frequency or Sinusoidal Response

Although any known time functions may be used as an input variable, the four functions most commonly used are shown in Fig. 5. The last type—the sinusoidal input—has a number of advantages over the

Impedance, pressure drop and flow rate on complex plane—(Fig. 6)



three others of Fig. 5 in a process system analysis:

• Since any function can be represented by a sine-cosine Fourier series, a system found to be stable for all sinusoidal inputs will be stable for all inputs.

• The analog circuit of Fig. 4 may be treated exactly as an alternating-current circuit, and the mathematics of a.c. circuits may be applied, and a good estimate of system behavior obtained, with a minimum of algebra.

• The disturbances caused by pumping equipment are essentially periodic in nature and, though not true sinusoids themselves, their behavior is fairly well represented by a sinusoidal input.

Fluid-System Response by Analogy

When a sinusoidally varying flow rate,

$$Q = Q_o - \alpha\omega t$$

is applied to the circuit of Fig. 4, the impedance expression may be taken out of the "s domain" by substituting the term $(j\omega)$ for s, where $j = \sqrt{-1}$. Recalling that $j^3 = -1$, $j^3 = -j$, etc., impedance is:

$$\frac{\Delta P\,(j\omega)}{Q\,(j\omega)} = Z\,(j\omega)$$

$$= \{(R_V+R_L) - R_V M_L C_B\omega^2 + j\,[(R_V R_L C_B + M_L)\,\omega]\} \div$$
$$\{1-(R_V R_L C_A C_B + C_A M_L)\,\omega^2 +$$
$$j\,[(C_A R_V + C_A R_L + C_B R_V)\,\omega - (R_V M_L C_A C_B)\,\omega^3]\}$$

The impedance $Z(j\omega)$ is now in the form of the ratio of two complex numbers,

$$Z\,(j\omega) = (c + dj)/(a + bj)$$

When this is reduced to a single complex number of the form $A + Bj$, it may be plotted as a vector of magnitude $|Z|$ and phase angle ϕ, as shown in Fig. 6.

Since $(a + bj)\,(a - bj) = a^2 - b^2j^2 = a^2 + b^2$, we may rationalize the denominator by multiplying numerator and denominator by $(a - bj)$:

$$Z\,(j\omega) = \frac{(c + dj)\,(a - j)}{a^2 + b^2}$$

$$= \frac{(ac - bd) + j\,(ad - bc)}{a^2 + b^2}$$

The impedance expression may then be written:

$$Z\,(j\omega) = \frac{ac - bd}{a^2 + b^2} + j\left(\frac{ad - bc}{a^2 + b^2}\right)$$

Asymptotes, intercepts, slopes and phase angles—Table III

$\lim_{\omega\to}$	$\lvert G\rvert$	Condition on s^k	Slope	Phase angle, ϕ
	∞	$k>0$		
	$K\,(a_o/b_o)$	$k=0$	$-k$	$-90\,k$ deg.
0	0	$k<0$		
0	0	$k>0$		
∞	$K\,(a_m/b_n)$	$k=0$	$m-n-k$	$90\,(m-n-k)$ deg.
0	∞	$k<0$		

$$= A + Bj$$

The magnitude of the response of ΔP to a sinusoidal flow input $Q(t)$ at constant frequency is thus:

$$|\,\Delta P/Q\,| = |\,Z\,| = \sqrt{A^2 + B^2}$$

The phase angle between input and output is given by

$$\phi = \tan^{-1}\,(B/A)$$

When the inertance effects are more dominant than the capacitance effects, the change in pressure will lead the changes in flow by an angle $+\phi$. Conversely, when capacitance is dominant, the pressure will lag the flow by an angle $-\phi$. When the two effects are exactly equal (a "tuned circuit"), or in steady state where neither is effective, the input and output are in phase.

Obviously, the expansion algebraically of $Z(s)$ to $|\,Z\,(\omega)\,|$ and then numerical point-by-point evaluation of $|\Delta P/Q|$ for all frequencies would be extremely tedious. However, we may sketch the behavior of the system by considering the extreme cases, where $\omega\to 0$ and $\omega\to\infty$.

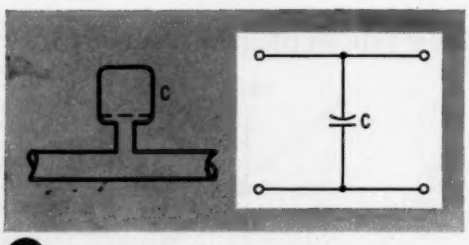
The Asymptotic Frequency-Response Plot

Any transfer function $G(s)$ may be arranged into the standard form:

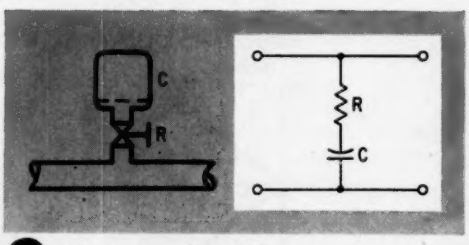
$$G\,(s) = (K/s^k)\,(a_m s^m + a_{m-1} s^{m-1} + \ldots + a_1 s + a_o) \div$$
$$(b_n s^n + b_{n-1} s^{n-1} + \ldots + b_1 s + b_o)$$

When the limit of this function is taken for the two extreme cases $\omega\to 0$ and $\omega\to\infty$, the value of $|G|$ may be evaluated at these points.

Some additional piping elements . . .

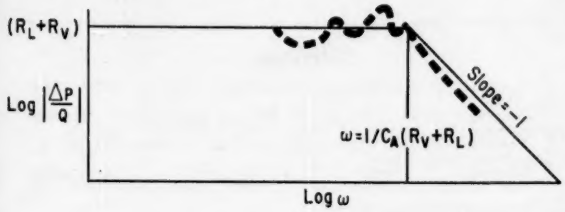


A Air-dome in line.

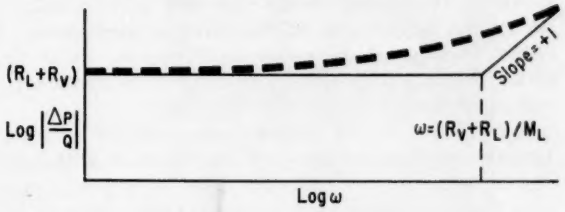


B Air-dome with choke.

Frequency-response plot for fluid-process system of Fig. 1—(Fig. 7)



Frequency-response plot for system without capacitance—(Fig. 8)



When log $|G|$ is plotted against log ω, the asymptotes to the curve may be drawn out from their intercepts. The asymptote at $\omega \to 0$ will be a line parallel to log ω, and the asymptote at $\omega \to \infty$ will have a slope determined by the degree of the polynomial in s, as shown in Table III.

Returning to our expression for impedance in the "s domain," and referring to the standard form of the transfer function and Table III, we obtain, when $K = 1$, $k = 0$, $m = 2$ and $n = 3$:

$$\text{At } \omega \to 0, \begin{cases} |G| = a_o/b_o = (R_L + R_V)/1 \\ \text{slope} = 0 \\ \phi = 0 \end{cases}$$

$$\text{At } \omega \to \infty \begin{cases} |G| = a_m/b_n = R_V M_L C_B/R_V M_L C_A C_B = 1/C_A \\ \text{slope} = m - n = -1 \\ \phi = -90° \end{cases}$$

The asymptotes will be two straight lines on a log-log plot, of the form:

$$\log |G| = c \log \omega + b$$

and the two will intersect at $|G| = R_L + R_V$, since the asymptote for $\omega \to 0$ has a slope of zero and that for $\omega \to \infty$ has slope of -1.

Equating the two lines for a common value of $|G|$:

$$\log (R_L + R_V) = -\log \omega - \log C_A$$
$$-\log \omega = \log C_A (R_L + R_V)$$
$$\omega = 1/C_A (R_L + R_V)$$

With the intersection of the two asymptotes fixed, and the slope of both determined, we may plot them as shown in Fig. 7. From the sketch, it is seen that at very low frequencies, the curve is close to the line $\omega \to 0$ but begins to deviate as the "breakpoint"—$\omega = 1/C_A(R_L + R_V)$—is approached. Beyond this point, the curve approaches the $\omega \to \infty$ line.

The degree of deviation near the breakpoint is a function of all the circuit elements. Where the curve falls below the $\omega \to 0$ line, capacitance is dominant. When curve is above this line, inertance dominates.

Beyond the breakpoint, the pressure becomes less and less sensitive to the variation in flow; that is, beyond this point the system is itself a pulsation dampener. An electrical engineer would call such a system a low-pass filter, which passes low-frequency pulsations but damps out high-frequency pulsations.

Capacitance Has Big Effect

It should be noted that the value of C_A is largely responsible for the location of the breakpoint. When C_A becomes quite small, as would be the case in a liquid system whose capacitance is due only to elasticity of the liquid and piping, the breakpoint will be at an extremely high frequency before damping occurs in the system.

Consider the worst case—an incompressible fluid in a completely rigid system. The expression for the system reduces to:

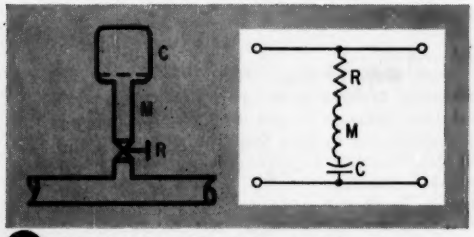
$$Z(s) = \Delta P(s)/Q(s) = R_V + R_L + M_L s$$

Slope of the $\omega \to \infty$ line is $+1$ and the intercept is M_L. Equating the two asymptotes at the breakpoint,

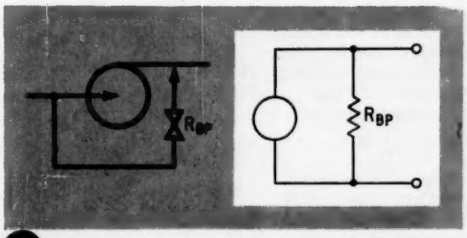
$$\log (R_V + R_L) = \log \omega + \log M_L$$
$$\omega = (R_V + R_L)/M_L$$

The asymptotes are sketched in Fig. 8. From Fig. 8,

. . . with electrical analogs—(Fig. 9)



C Air-dome with choke and inertance.



D Bypass valve; also pump leakage.

it is apparent that the pulsation becomes worse with increased frequency.

Addition of capacitance to a system in the form of surge tanks, air domes and diaphragms to eliminate pressure pulsation is a long-established practice. However, the analog circuit approach permits calculation and adjustment of the system parameters—either in original design or modification—so as to make the system self-damping. (Fig. 9 shows the circuit equivalents of some of these elements.)

Many other circuit elements are possible, such as bypasses with capacitance or inertance or both. It should be borne in mind when developing a fluid circuit that resistance and inertance always appear in the flow path, and incapacitance always appears across the circuit connected to ground pressure. Depending upon the arrangement of elements in the system, many different types of system behavior may be achieved.

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A derivation of elastic capacitance in lines and tanks and an explanation of distributed and lumped parameters in a system

The third equation presented to illustrate the three types of fluid-system capacitance (i.e., material storage) represents the capacitance, due to pressure, of line and tank expansion. The following derivation is based on elastic capacitance due to radial loading only:

$$r = r_o + (pr_o^2/Eh)$$

Taking the derivative of r with respect to p,

$$dr/dp = r_o^2/Eh$$

By definition,

$$V = \pi r^2 l$$

and therefore

$$dV/dr = 2\pi rl$$

Multiplying these two derivatives,

$$(dV/dr)(dr/dp) = dV/dp = (2\pi rl)(r_o^2/Eh)$$

Manipulating this expression for dV/dp, the rate of change of volume with pressure,

$$dV/dp = r(2\pi r_o^2 l/Eh) = \left(r_o + \frac{pr_o^2}{Eh}\right)\left(\frac{2\pi r_o^2 l}{Eh}\right) = \left(\frac{D_o}{2} + \frac{pD_o^2}{4Eh}\right)\left(\frac{\pi D_o^2 l}{2Eh}\right)$$

$$= \frac{D_o^2 l}{4Eh} + \frac{pD_o^2 l}{8E^2 h^2}$$

But $dV = Qdt = Cdp$. Therefore, capacitance is

$$C = \left(\frac{\pi D_o^2 l}{4Eh}\right)\left(1 + \frac{pD_o}{2Eh}\right)$$

The second factor on the right side of this equation can be dropped, because the denominator of its second term is always, in practical cases, much larger than the numerator.

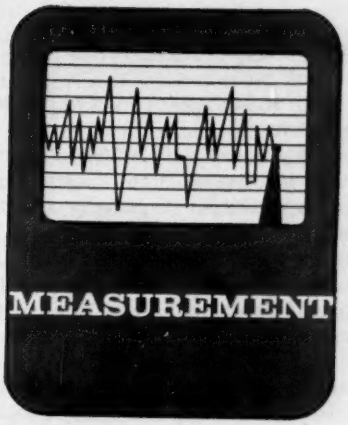
Distributed and Lumped Parameters

"In piping, the three parameters R, L and C relate flow to pressure. These parameters are functions of length of the piping and of time. In linearizing, they are treated as functions of time. They can be considered also as functions of space. Then, instead of L, R and C, they become L/unit length, R/unit length, etc., and are called distributed constants.

"Generally, however, the parameters may be lumped over small distances. For example, a long pipe may be analyzed as five capacities, resistances and inductances rather than as one."[4]

NOMENCLATURE

A Cross-sectional area, sq. ft.	ΔP Pressure drop across system, lb./sq.ft.
B Bulk modulus of fluid, lb./sq.ft.	R Volumetric flow rate, cu.ft./sec.
C Capacitance, farads or ft.^{5}/lb.	Q Resistance, ohms or lb.-sec./ft.^{5}
D Diameter, ft.	s Laplace operator
E Modulus of elasticity, lb./sq.ft.	t Time, sec.
f Fanning friction factor	V Volume, cu.ft.
g Gravitational constant, ft./sec.^{2}	X Reactance, ohms or lb.-sec./ft.^{5}
G Transfer function (output/input)	Z Admittance, 1/ohms or ft.^{5}/lb.-sec.
h Wall thickness, ft.	Y Impedance, ohms or lb.-sec./ft.^{5}
j $\sqrt{-1}$	α Amplitude factor in time function
l Length, ft.	γ Adiabatic exponent (specific-heats ratio)
L Inductance, henrys	ρ Density, lb./cu.ft.
M Inertance, lb-sec.^{2}/ft.^{5}	μ Viscosity, lb./ft.-sec.
p Pressure drop across pipe or vessel wall, lb./sq.ft.	ϕ Phrase angle between input and output
P Pressure, lb./sq.ft.	ω Natural frequency, radians/sec.



The key to better process control lies in the improvement of primary sensing elements and their application.

Progress in Plant Measurements

W. H. HOWE, P. H. DRINKER, R. M. GREEN, *The Foxboro Co., Foxboro, Mass.*

Man's ability to gage the conditions of his environment is a big factor in his chances of improving upon it. In industrial plants, where process measurements are of critical importance to the economics of plant operation, science and invention are making great strides toward accuracy, reliability and versatility of measurement. We are becoming more adept in selecting measurements that are truly significant and in applying instrumentation to provide these measurements under plant operating conditions.

No longer are we completely dependent on the old standbys of temperature, pressure, flow and level. Analytical measurements of characteristics or composition of a material, rather than simply its condition, are increasingly used in the plant, not just in the laboratory. We are improving measurement transmission and are making important progress in computation of significant information not directly available from individual primary sensing elements. But good measurement alone does not make a plant profitable—the data must be cleverly used to guide the operation or it is not worth obtaining.

Since chemical processing is so dependent on proper measurement, we will attempt to highlight the status of developments in the plant operations area, with a look at what has happened since *Chemical Engineering's* 1957 process-control report and an attempt to prognosticate on the next four years.

We move in a stream of accelerating developments. Some measurements are quite fully worked out; others are rapidly increasing in capability and in application. Some—perhaps the most intriguing—are hardly beyond conception. Fig. 1 shows how newer measurement techniques have barely approached their potential in process plant use.

Condition-Measuring Equipment

Measurements of temperature, pressure, flow and liquid level are still the workhorses of chemical process control. With refinements both in the measuring elements themselves, and in application know-how that recognizes fully their capabilities, steady improvement in these key measurements continues.

Temperature—For normal ranges, existing equipment, properly installed and maintained is eminently satisfactory. Manufacturers have developed fast-response temperature elements, both electrical and mechanical, with one- to two-second time constants. These are rugged, reliable and suitable for operation under severe conditions of pressure, corrosion and erosion.

There is progress, too, in temperature measurements for extremely high values, for values near absolute zero, and in very high velocity gas streams. Although relatively few chemical processes now require them, these types of measurement may prove useful in the near future.

Pressure—Pressure-sensitive semiconductor elements that develop a resistance variable with pressure are still pretty much in the development stage. They combine steady-state pressure response with excellent dynamic characteristics. Additional development is necessary to provide industrially practical elements, but this is a promising direction.

Progress is being made, too, in the development of more-rugged and reliable high-pressure elements, particularly in ranges above 2,000 atm. Measurements of this type are important in certain high-pressure chemical processes. For low pressures, such as 0.3-3.0 in. of water, techniques in the use of metallic diaphragms have improved to the point where these more reliable elements are commercially available for nearly all applications.

Flow—To provide more-uniform control and improve calculations of plant balances and efficiency, there is strong demand for better accuracy in flow measure-

ment. Such computations involve determining flows, so irregularity in such measurements reflects as a corresponding uncertainty in over-all results.

Activity is directed both toward improvement in existing measurement techniques and a search for new and better approaches. The ASME Fluid Meters Committee is making steady progress, particularly with head meters (venturi, orifice and similar elements). At Southwest Research Institute, extensive tests on pulsating-gas-flow measurement have shed much light on the inherent difficulties of this common problem. And refinements in the design of differential-pressure instruments, coupled with better plant installation and maintenance, are providing major improvements in both accuracy and repeatability of flow measurements.

For many conductive liquids, particularly those not otherwise readily measured, the electromagnetic flow meter has achieved important commercial application. Primary devices that handle from a few cubic inches to thousands of cubic feet per minute are available for a wide variety of fluids, including corrosive and erosive liquids and slurries. Able to handle a wide range of temperature, these magnetic meters have sustained high accuracy with minimum maintenance. Too, they have the inherent advantage of not restricting the line. Often, total installed cost is less than for other devices of comparable accuracy and low pressure drop.

Another area of rapid progress in chemical processing operations is the use of turbine, or propeller, meters. Reasonably clean fluids are a basic requirement. Application of these meters, which have essentially a digital output, has made very accurate continuous ratioing or blending possible, as well as totalization of batches with an accuracy never before possible at the cost. Although the turbine meter itself is not new, the magnetic sensing mechanism and improvements in bearings and structural details have reduced friction and improved its reliability. With flow ranges as wide as 20-to-1, turbine meters are available for a wide variety of liquids in sizes of a fraction of an inch to over a foot.

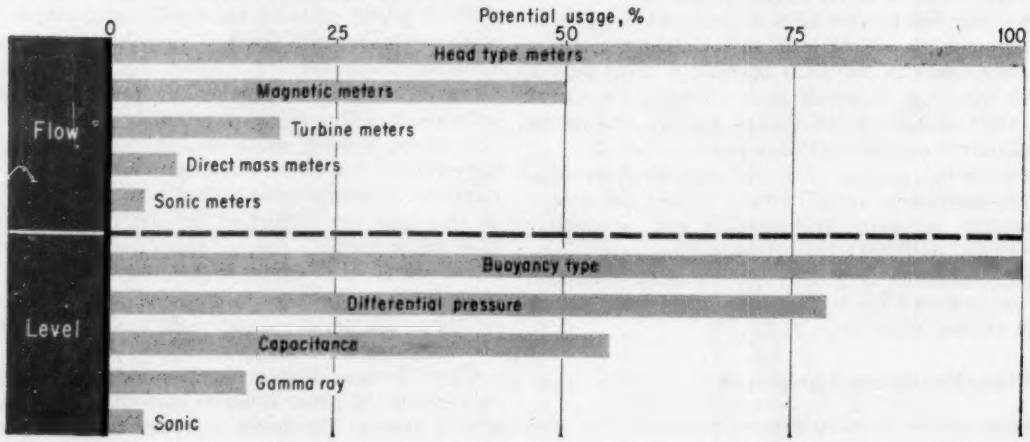
Instruments that measure flow by sonic principles have been patented and publicized but are available only for limited applications. The advantage of a restrictionless measurement for such nonconductive fluids as hydrocarbons makes sonic flow metering an important development to watch. Its use, combined with sonic measurements of density, has considerable promise for mass flow determination.

Increasingly accepted are mass flow devices that directly measure mass flow of fluids or solids. One type has a moving rotor in the flow line, which imparts a constant rotational velocity to the flowing material. This rotation of flowing material then acts on a second in-line element to produce a torque that is a direct measure of mass flow.

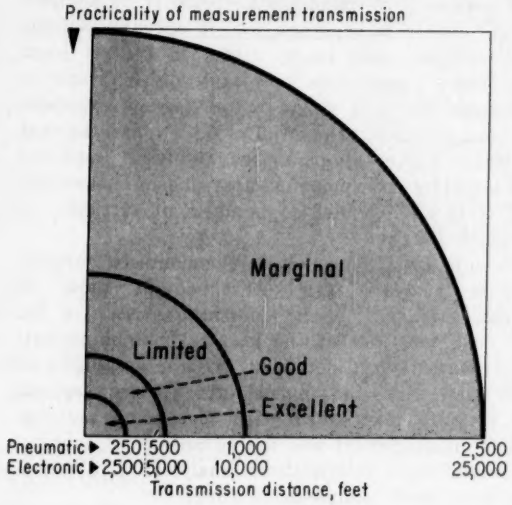
Another type of mass flow meter is based on the Corealis effect; it measures the reaction force resulting from the imparting of a rotational velocity to the flowing fluid. The rotation may be continuous at constant speed, or an oscillating mechanism with small angular displacement may be used. A recent development with a promising approach to measuring mass flow directly uses turbine-meter techniques. Although much equipment is interposed in the flowing stream, the advantage of a direct measurement of mass flow in many cases justifies the complications.

Level—During the last four years, differential-pressure measurement of liquid level has come into increasing use. Improved elements placed flush with the inner surface of a tank or pipe, and designed specifically for this application, have helped in this popularity. Compensation for both liquid and vapor densities has been applied to differential-pressure measurement of liquid level in nuclear pressurizing units. In these water-filled, electrically heated pres-

New instruments have good growth potential—(Fig. 1)



Here is how pneumatic and electronic transmission systems compare—(Fig. 2)



sure vessels, static pressures from atmospheric to 2,000 psi. are generated. The same approach is available for other liquids.

Gamma-ray level measurement has been applied, especially where nozzles in the vessel wall are undesirable, such as with highly corrosive liquids. In similar situations, capacitance measurement of level by a probe introduced through a limited-diameter aperture in the top of the vessel has been applied. Though difficulties have been experienced, sonic measurement of level—providing a noncontacting element with potentially high accuracy—has been tried and holds promise in tank-farm applications, for example, where a large number of levels must be measured and transmitted to a central location.

Analytical Instrumentation

With rapid development in stability, reliability and versatility, analytical instruments for measuring either characteristics or compositions of process streams have increased in importance. A characteristic may be a final product specification, such as density. But a density measurement can also be combined with a flow measurement to compute mass flow, or even correlated with composition in a binary mixture. A composition measurement, on the other hand, is directed toward the determination of a relative amount of one or more components in a mixture.

Characteristic Measurements of Gases

Thermal conductivity is an old and well-recognized technique. Resolution and stability, however, have been improved by a full order-of-magnitude, thus extending the potential of this measurement. Though thermal conductivity measurement is commonly used as the detector in chromatographic composition analysis, much application engineering must precede its use to full advantage in other areas.

Ionization detectors, operating on a sample stream of gas, have been developed to sense trace quantities of gases in a mixture. Methods now used to supply the necessary ionization energy include beta, gamma and X-ray, ultraviolet, radio-frequency, flame, and thermionic excitation. The ions produced in the gaseous mixture are collected on suitable electrodes by an applied potential, with current flow providing a measurement of the concentration of a specific component or group. This technique is still in its infancy, both as to measuring equipment and applications, but it certainly will grow rapidly because its high sensitivity permits trace analysis to parts per million, and even to parts per billion.

Measurement of specific gravity and flowing density of gases is receiving considerable attention. Progress has been made in direct measurement of gas density by a centrifugal density meter, which produces a differential pressure directly proportional to the mass of gas contained in a rotor spinning at a constant angular velocity. This and similar density measurements are useful in themselves and are also effective in combination with orifice metering for mass flow and other derived variables.

Experimental work has been done on gas-density measurement by determination of sonic velocities, and also by sonic absorption. As mentioned before, sonic density measurement may be combined with a sonic flow velocity measurement to determine mass flow.

Characteristic Measurements of Liquids

Gamma-ray instruments for measurement of liquid density are now available with stability down to 0.005 specific gravity. Considerable progress has been made in the simpler gravimetric determination of density, with great opportunity for further development.

Several devices for measurement of liquid viscosity are available, but the complex nature of the force, time and shear-rate relationships in non-Newtonian fluids requires extra attention. The measurement selected must actually determine the significant characteristic for the specific application. Recent progress in both apparatus and application has been great.

Turbidity instruments are available for measuring the total light transmission through a liquid sample and for measuring the ratio of transmitted-to-dispersed light (nephelometry). In many cases, however, neither of these measurements gives the desired information. A common waterworks and sewage measurement element, for example, is the Jackson turbidimeter, which depends upon subjective observation of the depth of liquid required to produce substantial blurring of the outline of a candle flame. Neither direct transmission nor transmission-dispersion ratio correlates reliably with "turbidity" as measured by this device. And there is a large field for this type of measurement, especially in consumer-goods products.

For some chemical products, there is a direct relation between dielectric constant and important product characteristics. For instance, Dr. Benjamin Thomas determined that there is a direct relation between change of octane rating and change of dielectric constant in certain catalytic fuel conversions. Other similar correlations are being worked out, and where they exist, dielectric constant leads to simple and reliable instrumentation.

Electrochemical measurements—such as pH, oxidation-reduction potential and conductivity—are steadily improving in both apparatus and application. Simple, single-stage measuring instruments are available, operating directly from the cells to produce display and control input. More-rugged primary elements to operate at higher line temperatures and pressures should simplify or eliminate sampling systems and reduce time delay. Faster-response elements would be useful in some applications. Constructed of special glass, pH electrodes are sensitive to very low concentration of sodium and other alkaline ions. Nonaqueous pH is being measured by filling reference electrodes with alcohol, or other polar organic solvents, and potassium chloride.

Automatic titration is an excellent example of an analytical instrument in which a sample of the measured liquid is chemically reacted with another material. For measurement of total acidity or total alkalinity of a buffered solution, automatic titration to neutrality is often the most direct approach. Much application progress has been made, with great opportunity for further development.

Titration is typical of the automation of a laboratory process for plant-stream operation. The basic principle is extremely simple. Accuracy and reliability are largely a matter of mechanical design, involving a high degree of ingenuity combined with sound, conservative engineering practice. Determination of the characteristic of a mixture by measurement of the heat of reaction when a suitable reagent is added presents a similar situation. Here, accuracy depends to a large extent on precise stabilization of flows and temperatures. Properly engineered, this technique facilitates a number of important characteristic measurements.

Finally, there appears to be a real breakthrough in refractometry, using fiber optics and similar techniques on moderate diameter rods or tubes. A better, simpler and more-rugged measurement of refractive index should result from current active work in this area.

Measurement of Composition

Vapor-phase chromatography is the outstanding development of recent years in the analytical measurement field, and has become well-established in many applications. Used only for measurement in most applications today, its demonstrated reliability is leading to increased use in closed-loop process control. The inherently intermittent nature of chromatographic measurement, however, often requires special techniques in control, including sample-data procedures.

Ionization detectors in chromatographs, as mentioned before, have made plant-stream trace analysis possible. There is progress, too, in speeding up the analysis cycle—speed being useful in control loops where process conditions may vary quickly, and in applications where a single chromatograph analyzes two or more streams sequentially. With apparatus that operates at higher temperatures, and with improved liquid-sampling equipment, vapor-phase chromatography is being extended to analysis of virtually all vaporizable liquids.

Although the spectacular developments in chromatographic analysis have overshadowed those in infrared, there has been important activity in the latter field, too. Use of the lead sulfide photovoltaic cell for near-infrared detection, and the possibility of similar units for the intermediate-infrared regions, could simplify plant-stream I-R measuring systems. Infrared measurement has the advantage of continuous, rather than intermittent, analysis, with potentially very short sample-delay time.

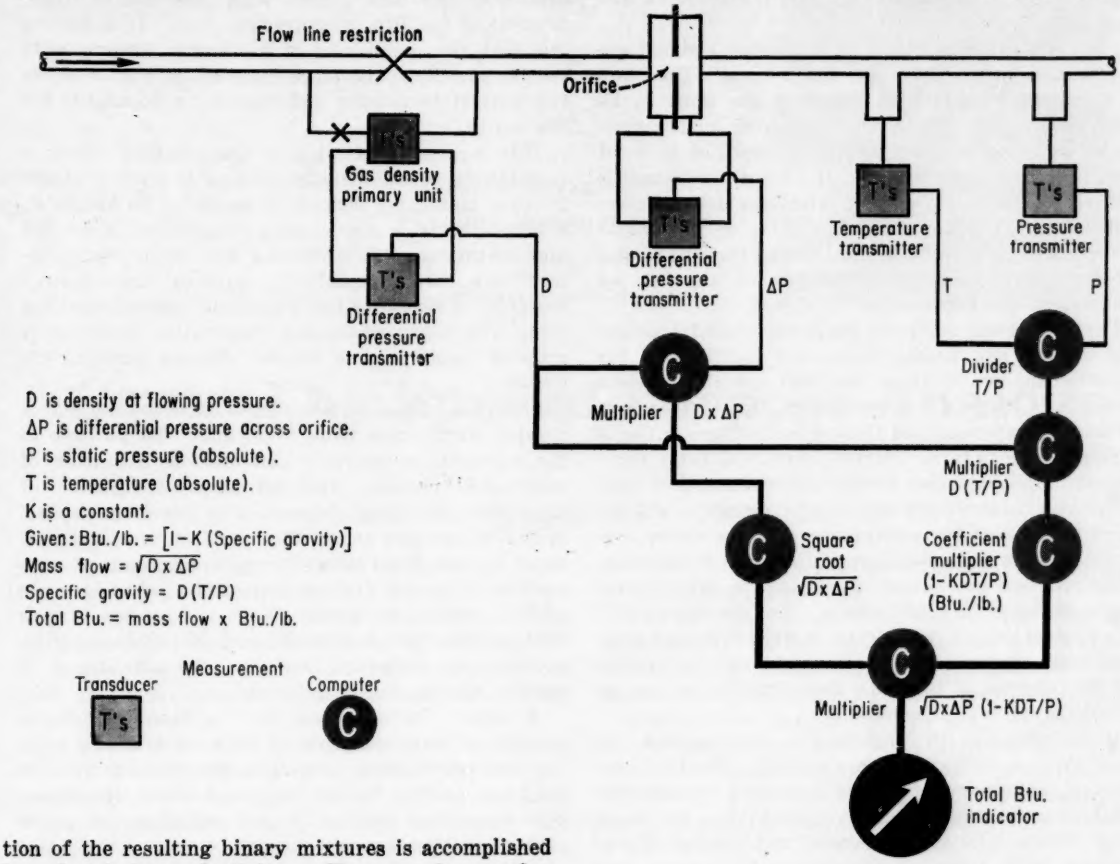
Polarography and allied amperometric measurements of composition can be highly selective and provide simple, accurate and reliable determination of composition in a number of ionizable liquids. There is an area for development of rugged plant-stream apparatus based on this approach. With this, as with many other measurement methods transplanted from laboratory to plant, ruggedness and reliability depend mostly on excellence of mechanical design.

Three composition techniques which have had limited penetration into plant-stream measurements are microwave spectroscopy, electron magnetic resonance and nuclear magnetic resonance. In the laboratory, these techniques are applied directly to determination of hydrogen and other elements with "half" values of nuclear spin. It is possible, also, to detect the presence of a methyl group, or olefinic or aromatic hydrogens. In many instances, these techniques are the only ones available for study of free radicals in biochemical and polymerization reactions. Since the principles involved are fairly straightforward, equipment based on them can and will be developed for application to chemical-processing plant streams.

Mass spectrometers are in use in a number of cases of in-plant applications, but where formerly they were the only solution in many cases, now vapor-phase chromatography has displaced them to some extent. Particularly effective in accurate determination of trace quantities, mass spectrometers remain in a class alone because of their cost and complexity; they are generally used where other analytical techniques are inadequate. An exception, however, is the helium-leak-test mass spectrometer. In-plant apparatus, it is seldom applied to continuous plant-stream measurement.

Use of ion-exchange columns to separate liquids by differential migration (liquid-phase chromatography) holds a promise of extending a well-established laboratory procedure into on-stream plant analysis. Detec-

By combining measured values in computer circuit, Btu. flow is obtained—(Fig. 3)



tion of the resulting binary mixtures is accomplished by electrical conductivity, pH or polarography. Though relatively new, the technique has potential in such analyses as ionized liquids and solutions containing solids.

The electrolytic hygrometer for determination of trace moisture content of gases is an excellent example of an analyzer specific to a single material in a mixture. The quantity of moisture per unit time contained in the flowing sample stream is read directly from this instrument. Except for a few "poisons," the composition of the gas stream has no effect on the reading of moisture. Paramagnetic oxygen measurement is in a similar class. Based upon a specific property or reaction of a particular component, several specialized analyzers measure the quantity of the components, independent of composition of the rest of the mixture.

Measurement Transmission

Modern process-measuring systems differ from the earlier glass-stem thermometers, sight gages and similar simple measuring devices, in that the primary measurement is transmitted to a central control room or equivalent information center. The information-transmission systems in chemical process operations fall into two broad categories—those for long and those for short distances, where long may be considered as over two miles. Fig. 2 indicates useful transmission distances for standard pneumatic and electronic systems.

For short distances, transmission was until recently either pneumatic or an electrical measurement, such as a thermocouple millivoltage, directly generated by the primary measuring element. Since 1957, electrical transmission systems have undergone remarkable development. Most major manufacturers have released designs of integrated electronic measurement, transmission and control loops, available for practically every type of measurement input. In most cases, the equipment is completely solid-state, with transistors or magnetic amplifiers but no vacuum tubes.

Most loops have transmitters, controllers and analog computer units that all have a common signal base, so that there is complete flexibility of interconnection, much the same as with the 3-15-psi. pneumatic transmission systems. Several different types of signal are offered, with a number of spans and ranges. In this country, a d.c. current signal with a "live" zero is gaining acceptance. This live zero has several advantages, including facilitating the two-

wire transmission system, which uses only a single pair of wires to provide both signal transmission and transmitter power supply.

The three common values of d.c. current signal are 10-50 milliamperes, 4-20 ma. and 1-5 ma. The ratio of maximum to minimum signal is the same in all three ranges. By minor modification of input circuitry of receiver instruments, it is possible in most cases to interconnect instruments from different manufacturers in a single system. Endless debates have been presented verbally and in writing on the merits of electric vs. pneumatic design, and on the advantages of the several electrical measurement signals; we won't start one here!

The future will see more progress in electrical system design, and among important possibilities for improvement are systems that will operate on their own from a single d.c. power source (battery backup) so that measurement and limited control are available during power failure. Current electrical loops functionally duplicate older measuring systems that have pneumatic transmission and control elements, and designs to enhance the advantages of these newer systems will take full advantage of electrical capabilities. Some progress has already been made in this country in the realm of intrinsic safety. Full development of this concept, which is accepted in British design practice, could increase the fundamental safety of electrical instruments, at the same time simplify design, installation and maintenance.

Great advances in long-distance transmission for interplant communications are evident. Though time-interval, impulse-counting and frequency telemetering continue to be useful in many applications, the major steps forward lie in pulse-coded and similar digital systems, with operation at teletype frequencies, and also in channels with operation at teletype frequencies, and also in channel with much wider band-pass and greater information-handling capacity.

Some development of conversion from primary-element measurement directly to digital signals has been carried out in special applications. As both intra- and interplant digital data handling increases, adaptations of these techniques for the CPI may be important. Though detailed treatment is beyond the scope of this discussion, this field of digital manipulation of measurement signals is of tremendous importance to the over-all measuring field.

Measurement by Computers

An analog or digital computer is not a measuring instrument in the usual sense. In many practical instances, however, the truly significant process information consists of a value or group of values that must be derived by computation from direct measurements. The increasing use of computers as a part of measurement, as distinct from control, is a major feature of today's practice.

Fig. 3 presents a typical example. The significant information desired is the total Btu. in a gas stream. Composition of the gas varies from 99-75% methane (from 1-25% of a known mixture of higher hydrocarbons), and flow varies, with flow control independent of the Btu. measurement loop. It is known, too, that Btu. per pound of gas varies linearly with specific gravity. The block diagram of Fig. 3 shows relations of measuring and computing apparatus for the device.

This is a good example of the situation where a variable value not directly obtainable from a single primary measuring element is desired. To handle it, after the variable is selected a computation is decided upon to produce it. Measuring and computing equipment are then assembled to produce the required variable. Presenting few technically new or startling ideas, this measurement and computation procedure is growing rapidly, with several factors boosting its growth.

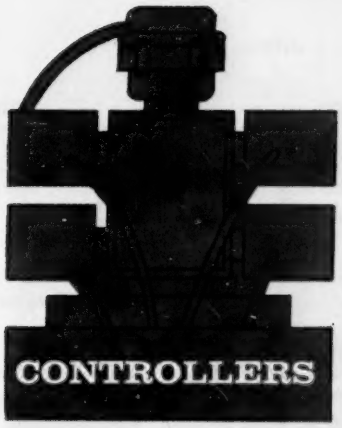
First, the increasing complexity of processing makes precise information more important. To go back to the example, an operator can observe indication of differential pressure and get an approximation of mass flow, especially if pressure is closely controlled. A skilled operator senses the "feel" of the plant and, aided by occasional laboratory determinations of composition, he gets a first-approximation operating guide of Btu. content variation. When the process is such that information on total Btu. is critical for quality, economy or capacity, however, the advantage of specific information is apparent.

A second factor, related to the first, is that the specific information provided by such a device helps the less-experienced operator, who cannot rely so fully on skillful interpretation of plant operations. The increasing application and reliability of plant-stream analytical measurements is a third important element in use of computers. Analytical information is a vital part of most measurement computations. The characteristic of the gas, in terms of Btu./lb., is basic to the example we have cited. Without this information, no computation would be practical. Conversely, the use of computation greatly increases the usefulness of analytical measurements.

The fourth, final factor that has boosted use of these special-purpose computers is improvement of computing equipment. Although it's beyond our purpose to describe computers, suffice it to say that analog computer elements are becoming available from several manufacturers, both for electric and pneumatic operation, fully compatible with standard transmission signals. For further discussion, see p. 205 of this report.

Conclusions

Progress in measurement can be summarized this way: areas showing the greatest improvement in the last four years have been analytical instruments and electronic transmission. Conditions measurements—the old standbys in processing—will be refined. But computers—both special-purpose and general-purpose—will emerge in the years ahead as instrumentation's most active development.



Chemical engineers can tailor these controllers, if they examine their plants fundamentally.

Control by Special-Purpose Analogs

GEORGE W. PLANT, *Wyandotte Chemicals Corp., Geismar, La.*

During the past few years, the chemical process industries have been bombarded with discussion of large digital-computer control systems. It seems only fair to pause and ask if the installation of such systems is in good engineering practice when the control systems that these computers must be used with are not wholly satisfactory.

Is it feasible to install a system that is theoretically capable of achieving truly optimal operation when the associated control equipment cannot hold a complicated process operation to within a 2-5% variation? And what of processes that can't economically justify a digital-computer installation? Is there a way for these processes to be optimized?

Without necessarily going to the expense of digital control computers, further improvement in chemical process control is needed. Look at some of the problems we face:

- Conventional control systems using off-the-shelf hardware have been pushed about as far as they will go. However, the automatic control of plant startups, upsets and shutdowns leaves much to be desired.
- Stream analyzers provide extremely valuable information about process operation, but it's not always easy to apply these analyzers to conventional control systems.
- Although conventional instruments in the common feedback control loop minimize process upsets, it would often be valuable to forewarn the control system of upsets that affect product quality or process efficiency.
- Nonlinear processes are quite difficult or impossible to handle effectively with conventional control.

Thus, many processing plants need improved control, but only a minority of them could probably economically justify a large computer-control installation. What is needed is a bridge to that more-formidable application, which will improve control at less cost. That bridge may be the use of standard pneumatic or electronic analog-computing elements to solve your particular control problem.

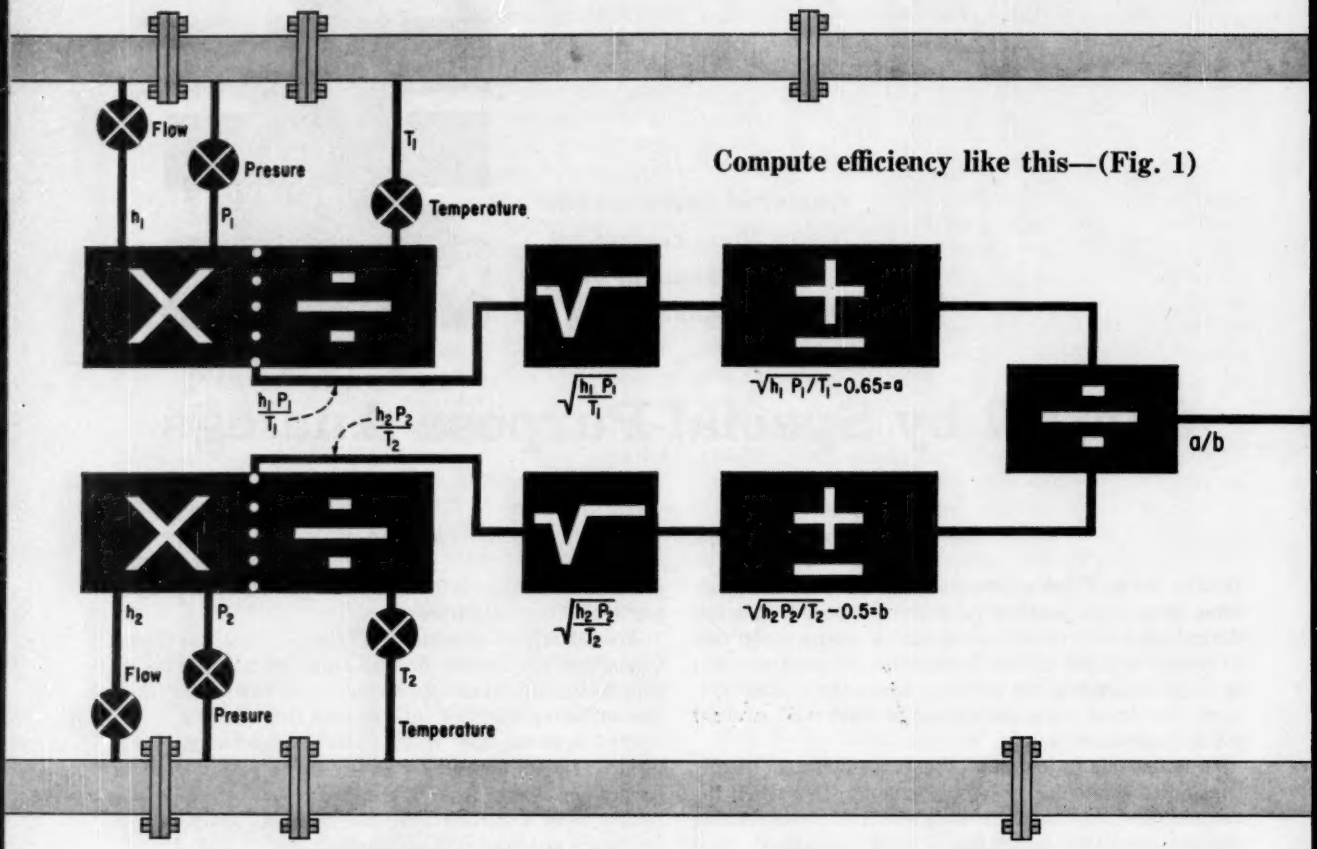
You shouldn't conclude, of course, that the large computers are useless, or that they are not capable of calculating optimum operating conditions. But they are no better than the information they receive or the control systems they reset. The most economical approach would appear to be to solve major process control problems first, and present the digital computers with a system that can truly be optimized, if the large machine still seems desirable.

Use of Analog-Computing Elements

Special-purpose analog elements can, through ingenious application, greatly extend our ability to control and optimize at a relatively low cost. Cost of pneumatic elements averages $150 per arithmetical function. Though more difficult to apply an average cost per function to electronic units, a good rule-of-thumb estimate is to double the cost of an equivalent pneumatic system. This low cost for the degree of computer control possible should make these systems highly attractive to smaller companies and small production units.

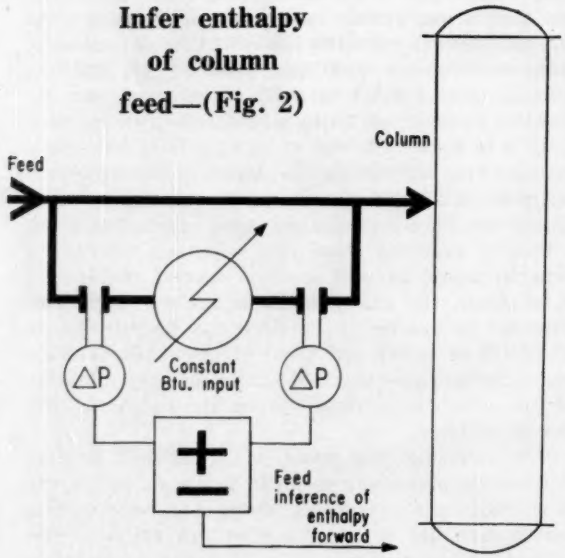
Readily available from some reputable instrument manufacturers, as well as from several analog-computer firms, the analog elements are standard components. Accuracies of the electronic components are about ¼% or better, and those of pneumatic ones are generally between ½% and 1%. By careful calibration of the system as a whole, system accuracies of ½-3% can be achieved.

Use of either homemade or off-the-shelf special-purpose computers can result in important savings in production costs by reducing energy requirements. Too, justification lies in better use of raw material, less wasted processing time due to upsets, a greater percentage of on-specification product, and reduced interprocess surge capacities.



Compute efficiency like this—(Fig. 1)

Infer enthalpy of column feed—(Fig. 2)

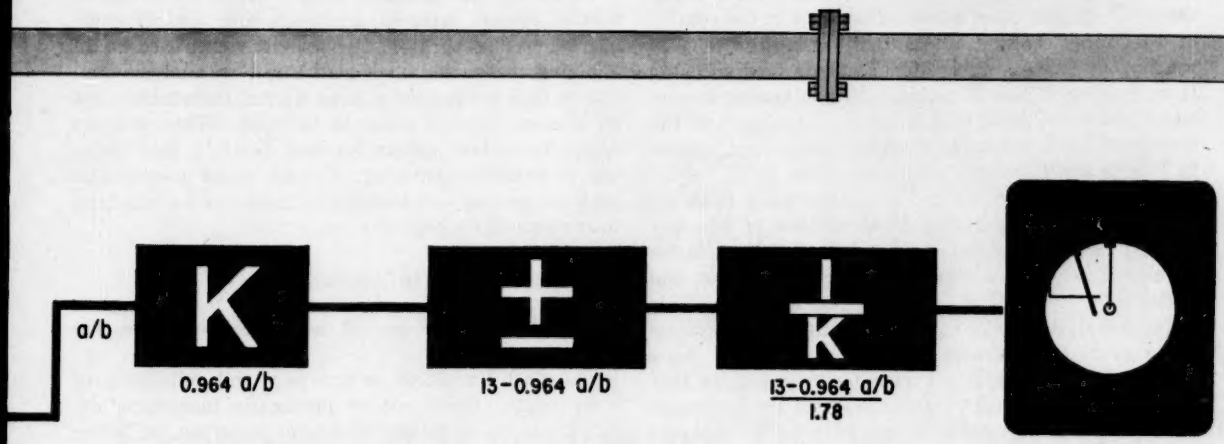


Although most engineers have not thought of them as such, many special-purpose analog controllers are already in use—some for many years. A common example is the control system used on larger steam boilers. The basic process has been well-known for years, and the instrumentation—all bugs long since removed—has become highly sophisticated and efficient. The key to success of this application is probably that detailed process knowledge has been available to many people. Its availability enabled the control engineer to thoughtfully apply multi-element control and computing relays.

If the steam-generating facilities are large enough to justify the cost, digital computer supervision and optimization is the next logical step in advancing their control. Every means short of this step has already been applied. This process, then, presents an excellent illustration of the process-industries potential for application of analog-computing elements in control problems—before moving on to application of the large general-purpose digital machines.

Combining Analog Elements for Control

Let's consider the use of analog elements in a case where efficiency is a function of two flows. The equation that represents efficiency is:



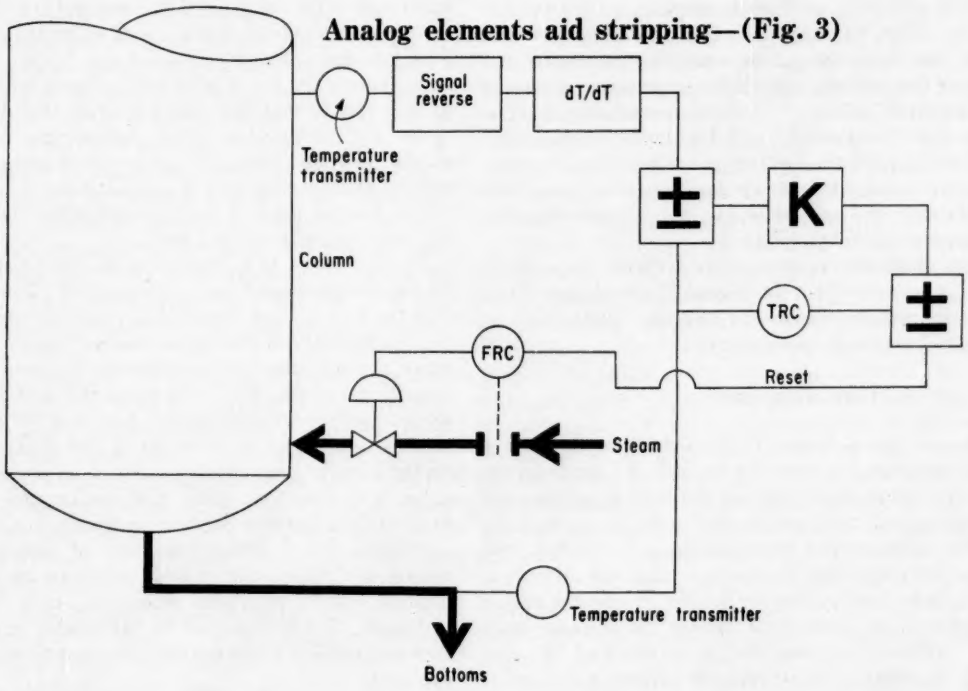
Efficiency =

$$\frac{13 - 0.964\left[\left(\sqrt{h_1P_1/T_1} - 0.65\right)/\left(\sqrt{h_2P_2/T_2} - 0.5\right)\right]}{1.78}$$

where h_1, h_2 are meter differentials; P_1, P_2 are steam pressures; T_1, T_2 are steam temperatures. The block diagram of Fig. 1 shows the combination of elements required to compute this function.

This computing can be done either pneumatically or electronically, or by a combination of both. Using pneumatic elements, the cost for the entire system, including the six transmitters, is approximately $3,000. Such a computer has high potential as a guide for operators of a complicated process, and it could be expanded to include a control function if the nature of all the critical variables was well-defined. Such a system should be calibrated as a unit, rather than as individual elements, to achieve necessary accuracy. But in this case, trend of efficiency is probably more important than its absolute value.

Analog elements aid stripping—(Fig. 3)



Turning to another example, the value of feed enthalpy is sometimes of major importance in the control of distillation columns. No enthalpy-sensing device is readily available, however. Thus, where feed enthalpy is an important consideration, a simple analog system could be used to infer this variable. Complexity of the feed composition dictates whether this system, shown in Fig. 2, can be used to infer enthalpy.

In Fig. 2, a feed stream runs through a heat exchanger that provides a constant number of Btu. per unit of time. The difference in differential pressures developed across orifices in the exchanger inlet and outlet lines provides the inference of enthalpy. This difference signal can be used to reset the control system or to guide the operator's control of the unit. As a control reset, it would act as a feedforward, so that accuracy of the enthalpy inference would not have to be too great. In some instances, application of this simple system could save the cost of an expensive analyzer.

A third example of the usefulness of these special-purpose devices will be found in stripping-column control. When columns are operated at atmospheric pressure, a large loss can occur in the bottoms if the overhead product strips out of the steam at a temperature only slightly less than the boiling point of water.

If conventional temperature control is used, and a temperature of 210-211 F. is required to strip the product, excess water vapor may be forced out of the overhead because of reset action and overshoot of the controller. Since 212 F. is the boiling point, heat input in excess of that required to produce boiling is not "felt" by the controller. Because of its reset action, the controller continues to add more and more steam. Temperatures below 209-210 F., on the other hand, result in losses of product in the bottoms.

Analog elements, used as a temperature-differential override (Fig. 3), can help this situation. In this system, the lower temperature-transmitter signal and the upper temperature-transmitter signal are combined in an algebraic adder. If both temperatures increase, output remains constant. If the lower temperature stabilizes because the boiling point has been reached, the output tracks the upper temperature-transmitter and, through the second adder, cancels or overrides the temperature control signal.

Many applications, other than these three cited here, will become apparent to you if you closely study your own process operations and the application of analog techniques to their control.

Some Special Considerations

It is not the purpose of this article to describe a process analysis, but the more basic such a study is, the higher its value. The value of the control system and the degree of complexity that can be practically achieved increase with greater process knowledge. Not usually applied except to processes that are difficult to control, these special-purpose controller systems should be analyzed on a dynamic rather than steady-state basis. Difficulty of analysis is determined by complexity of relationships between control variables.

To derive the greatest benefit from an advanced control system, process engineers and control engineers must cooperate. Two bonuses then accrue in applying the analog elements. First, an analysis similar to that needed for a large digital installation, but on a much smaller scale, is involved. When a large computer-control system becomes feasible, this training of personnel pays off. Second, closer cooperation between process and control engineers can be beneficial to any processing organization.

Four Limitations to Application

Four things limit use of these special-purpose controllers.

The first limitation is accuracy and reliability of components. Electronic or pneumatic measuring devices seldom maintain long-term accuracy of better than ½-¾%. Pneumatic computing elements have similar accuracy. Though capable of higher accuracies than the pneumatic devices, electronic computing elements tend to fail completely when a mulfunction occurs. Operational failure of the special-purpose computers can be very detrimental to the control system. Instrument manufacturers should continue their push for higher accuracies and reliabilities so that various types of computer control can be used to full advantage.

Function capabilities of hardware is a second limitation. For example, differentiation and integration must be time-based. If you wish to take the derivative of y with respect to x, the independent variable x must be time-scaled. And to provide better control of nonlinear processes, a good series of adaptive analog elements is badly needed.

Third, most technicians and engineers have had little experience with the type of process and control-system analysis necessary to apply analog elements effectively. This training can now be gained only by actual experience, though the use of advanced systems will certainly dictate the formal training required of future engineers and technicians. The engineering talents required are mathematics, chemical engineering and control engineering, and minimum technician requirements are, at least, a strong high-school background in chemistry, physics and math.

Finally, there is a limitation in the receptivity of operations personnel and management. This requires that the first system installed be relatively simple, have high probability of giving the desired results, and solve some problem that is foremost in the minds of the operations group. Not only must the first system be exceptionally well-engineered, but a high degree of salesmanship may be required of the designer. Sold on the basis of economy or easing of an operating difficulty, a system that meets installation and operation expectations tumbles barriers to acceptance.

Despite these limitations, use of special-purpose analog controllers can provide solutions to previously difficult control problems at nominal cost. Relatively untapped, this field should be thoroughly explored before any move is made toward more-complicated control systems.

Sometimes it is necessary to obtain plant data. Here is one way to do it.

Process Dynamics by Pulse Testing

JOEL O. HOUGEN, *Monsanto Chemical Co., St. Louis*

Methods for experimentally determining the dynamic response characteristics of physical systems have been evolving for over twenty years. As a result, successful procedures have become fairly well entrenched in specific areas, and the neophyte may become confused by the claims of proponents of various testing methods. This may lead an inexperienced investigator, working with entirely different or unique systems, to choose a testing method that may not be the most efficient or economical for his particular situation. Once committed, it may be difficult to adopt a new test procedure.

A useful criterion is to select that procedure which can be employed without necessitating curtailing process operations or interfering with normal production. The time the test crew occupies a plant should be minimized. It is, moreover, helpful if the test is typical and realistic of normal plant performance. A balance should be made between the investment in developing a highly skilled testing crew, carefully planning the testing program and in more extensive processing and analysis of the data, and the time the crew occupies the plant. The less time the plant is actually involved, the greater the demands upon the crew, preparation for the work and analysis of the data.

The classical method of procuring dynamic response characteristics is the direct sinusoidal forcing method. This consists of varying a significant system input (independent variable) in a sinusoidal manner, and observing the response of the system outputs (dependent variables) to this sustained disturbance. The procedure is repeated at discrete frequencies until a sufficient spectrum is covered. The frequency responce information is contained in the ratio of output to input amplitudes and the shift in the phase of the output relative to the input. Test frequencies covering a hundredfold range are sometimes required.

If wave distortion and signal corruption occur in either input or output signals, considerable difficulty may be encountered in recovering the desired information directly. In such instances, data smoothing and correlation techniques may be required.

In any event, the steady-state sinusoidal method is certain to be very time consuming and expensive when applied to processes familiar to chemical engineers, and should be used only as a last resort.

Two techniques have been proposed that minimize the time for testing; in each case, the systems are excited by disturbances of input variables. These techniques are:

1. The random-input method.
2. The pulse method.

In the former, auto- and cross-correlation techniques are used to extract the pertinent relationships between an input-output pair. It is implicitly assumed that the system is excited at all desirable frequencies.

This method has been described by a number of writers, and very recently has been applied to a typical chemical engineering operation by Gallier. He reports the need for a minimum of about 3,000 discrete time data in order to ensure an adequate description of the system studied.

The testing technique to be discussed here, and which is recommended as being the most effective, is the pulse method. In this case, a known but somewhat arbitrary pulselike variation in an independent variable is introduced, and the response of the system to this disturbance is determined by an analysis of the variations in the outputs. The principal requirements are that the inputs and outputs be recognizable and that the desired dynamics of the system be actually excited. If these and other reasonable precautions are exercised, it is possible for a relatively untrained experimenter to retrieve system data with incredible fidelity and to reduce these to frequency response form for further analysis.

The theoretical relationships between the direct

steady-state sinusoidal method and the pulse method shows that both techniques yield identical information for linear systems. A system described by an nth-order ordinary linear differential equation being forced sinusoidally may be represented by the relationship of Eq. (1):

$$\sum_{0}^{n} a_k \frac{d^k y(t)}{dt^k} = A \sin \omega t \tag{1}$$

where ω is the angular frequency.

Introducing the Laplace transform,

$$\int_0^\infty e^{-st} y(t)\, dt = Y(s) \tag{2}$$

and assuming initial conditions of zero on $y(t)$ and its first $(n-1)$ derivatives, we find

$$\left(\sum_{0}^{n} a_k s^k\right) Y(s) = \frac{A\omega}{s^2 + \omega^2} \tag{3}$$

or

$$Y(s) = \left(\frac{A\omega}{s^2 + \omega^2}\right) \frac{1}{G(s)} \tag{4}$$

where $G(s) = \sum_{0}^{n} a_k s^k$.

Provided $G(s)$ is a Hurwitz polynomial, which implies a stable physical system, the steady-state response to the sinusoidal forcing is directly obtained.

$$y_{ss}(t) = \sum_{1} \text{Residue} \left. \frac{A\omega e^{st}}{G(s)(s^2 + \omega^2)} \right|_{\substack{s = +j\omega \\ s = -j\omega}}$$

$$= \frac{Ae^{j\omega t}}{2jG(j\omega)} - \frac{Ae^{-j\omega t}}{2jG(-j\omega)} \tag{5}$$

Each complex function can be resolved into a magnitude and associated phase angle so that

$$y_{ss}(t) = \left| \frac{A}{G(j\omega)} \right| \sin(\omega t - \phi(\omega)) \tag{6}$$

For any arbitrary Laplace-transformable input $x(t)$, Eq. (4) may be written as

$$Y(s)/X(s) = 1/G(s) \tag{7}$$

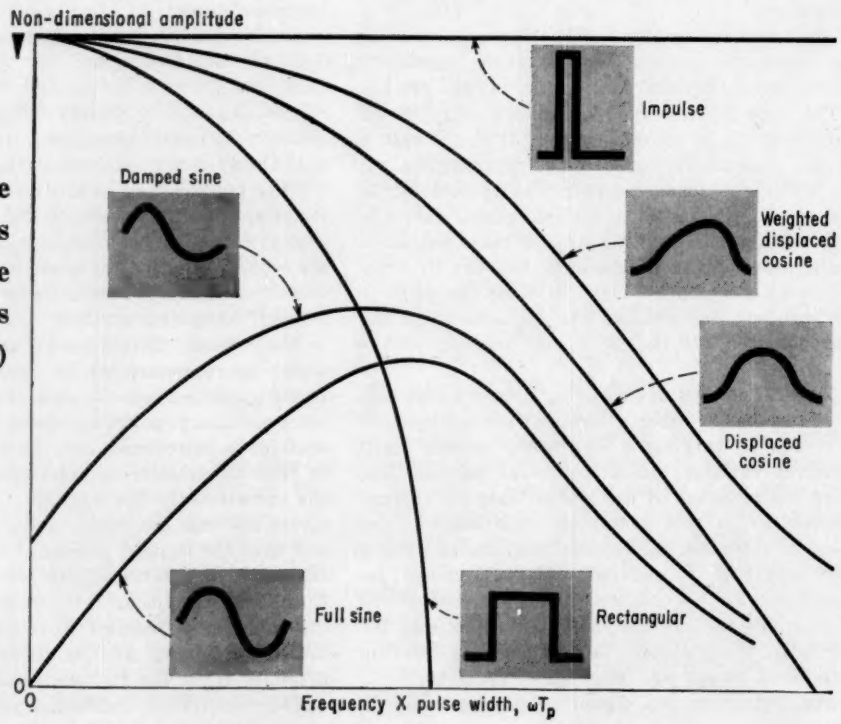
or

$$\frac{\int_0^\infty e^{-st} y(t)\, dt}{\int_0^\infty e^{-st} x(t)\, dt} = \frac{1}{G(s)} \tag{8}$$

If both $y(t)$ and $x(t)$ are continuous functions of a bounded variation, which return to their initial values after a finite time and remain constant thereafter, the above integrals exist and can be evaluated. Functions as specified above may be called pulse functions.

Evaluation of the integrals, with $s = j\omega$, usually accomplished by numerical methods employing a digital computer, yields the performance function, as the ratio of the Fourier transforms is frequently called.

$$[PF](j\omega) = \frac{\sum_{k=1}^{n-1} y(k\Delta t)\, e^{-j\omega k\Delta t}}{\sum_{k=1}^{n-1} x(k\Delta t)\, e^{-j\omega k\Delta t}} = |G(j\omega)|\, e^{j\phi(\omega)} \tag{9}$$



Amplitude functions for some pulse shapes —(Fig. 1)

Oscillographs of pulse tests—(Fig. 2)

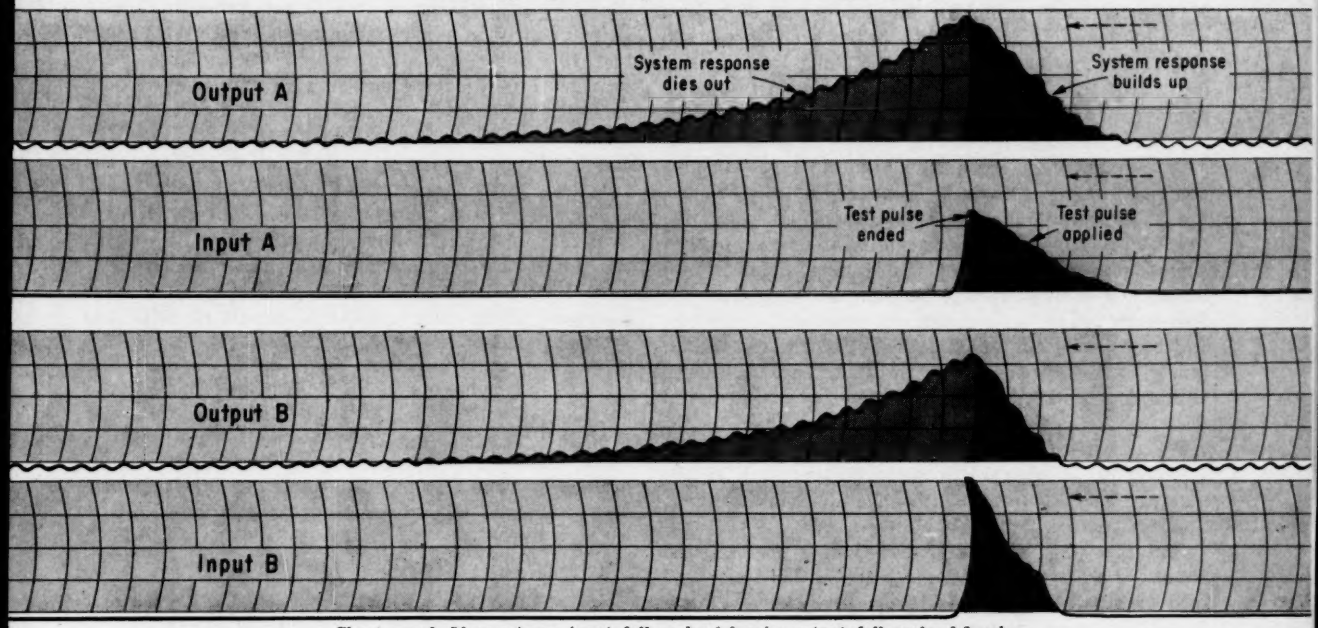
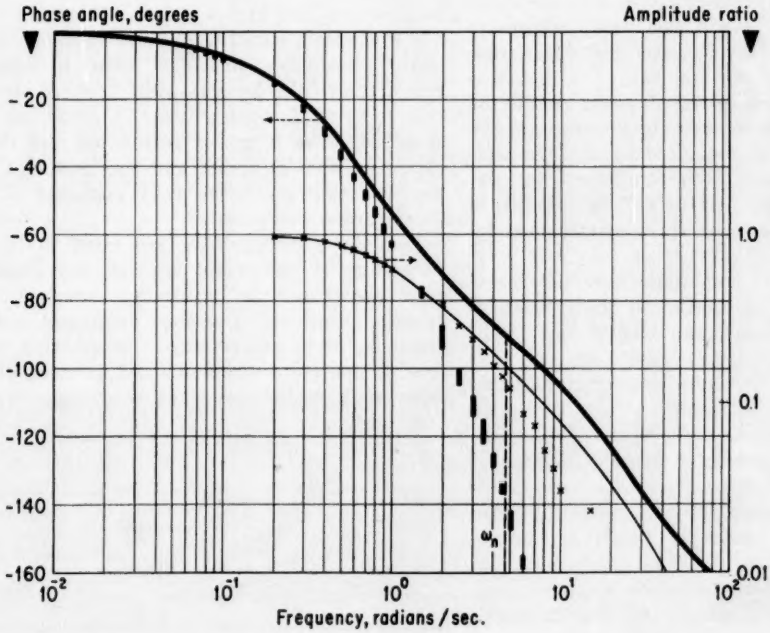


Chart speed, 50 mm./sec.; input full scale, 1.0 psi.; output full scale, 0.2 psi.

for the case where Δt is a sectionally fixed increment width, used to subdivide the time coordinates of the pulses.

Results for linear systems are thus identical with those obtained through direct sinusoidal forcing.

The nature of the pulse used is exceedingly important and should not be chosen at random. While it need not conform to any particular theoretical form, depending upon the particular physical system being studied and the objectives being sought, some forms



Frequency response data from tests—(Fig. 3)

are superior to others. The harmonic content of pulses of definite shape have been studied extensively. Nondimensional amplitudes for a selection of pulses, as functions of frequency, have been presented graphically by Lees[2] and Hougen and Walsh.[1] The latter also discuss phase angle relationships and a number of practical considerations concerning test pulses.

In a qualitative way, some properties of pulselike functions are illustrated in Fig. 1. For convenience, the amplitudes of the one-sided pulses are adjusted to give a relative amplitude of unity at zero frequency.

In some respects, the most convenient pulse from a theoretical point of view is the impulse, since over the frequency spectrum this has a constant amplitude and zero phase angle. Practically, however, such an input is almost impossible to inject into a real system, although it may be approximated in some special cases.

With respect to phase angle, all pulses that are symmetrical about a vertical coordinate (such as the rectangle or displaced cosine) have identical behavior, the phase angle being equal to $-\omega T_p/2$.

The full sine, or modifications of it such as the damped sine, exhibit maxima in amplitudes but have zero or small amplitudes at zero frequency. These forms are very useful for exciting a system in a particular frequency range—a range that may be selected by choosing the appropriate pulse width.

Almost never does the situation arise where the shape of the input is insignificant, even when the input pulse is short compared with the length of the output. Sometimes, such as might occur if a highly concentrated dye or solution is injected into a mixing system, the input can be assumed to be a short rectangle closely approximating an impulse. In such instances, analysis of output responses may be sufficient to yield useful information. It is wise, however, to have descriptions of the inputs whenever possible since generally their shape influences the results obtained.

Many examples have been given showing results of pulse testing systems of interest to chemical engineers. These have been summarized by Hougen and Walsh[1] and no review need be given here. In our experience the method has yet to fail in procuring useful information on systems from components to full-scale plants.

In order to illustrate the technique from the execution of the test to the interpretation of the frequency response results, some recent unpublished work will be described.

The objectives were to determine experimentally the dynamic characteristics of a specific pneumatic signal transmission system and note the agreement between these results and those predicted from a simplified theoretical model. The forcing pulse was introduced by rather quickly bringing a rubber stopper, in the center of which was the outlet of an air jet, up to the enlarged end of the tubing. The line terminated in a volume of known capacity. Sensitive transducers were used to measure pressures in the terminal chambers and time histories recorded on an oscillograph. With some practice, a ramp type of pulse could be approximated, the input pressure rising quite linearly to a maximum and abruptly returning to zero (gage) when the stopper was quickly withdrawn. Pulses of various lengths and shapes could easily be generated by this simple technique.

Fig. 2 shows the experimental data for two distinctly different pulses, while Fig. 3 presents the frequency response information derived from them. The close agreement between the two tests is confirmation of the reliability of the method as well as the validity of the assumptions of linear behavior.

A simplified theoretical relation adequate for some purposes, along with constants associated with the system tested, is shown below:

$$\frac{P_{out}}{P_{in}}(s) = \frac{1}{\frac{s^2}{\omega_n^2} + \frac{2\zeta s}{\omega_n} + 1} \qquad (10)$$

where P_{out}, P_{in} are transforms of output and input pressures. The undamped natural angular frequency ω_n is 4.69, and the damping factor ζ is 2.96. Other constants are

Cross-section of tube	1.57×10^{-4} sq.ft.
Tube length	200 ft.
Terminal volume	2.9×10^{-2} cu.ft.
Density	2.3×10^{-3} slugs/cu.ft.
Velocity of sound	1.13×10^{3} ft./sec.
Fluid resistance	6.4×10^{-2} lb.sec./ft.^{4}

Agreement between the simplified model and experiment is good for amplitude out to a frequency equal to the undamped natural frequency ω_n, or 4.7 radians/sec. (0.75 cycles/sec). Phase angles show appreciable deviations beyond 1 rad./sec. At higher frequencies, a more complex model is required in order to give better agreement with experimental data.

Attempts to procure frequency response information on this system by direct sinusoidal forcing led to inconsistent and highly questionable data beyond ω_n. The pneumatic signal was produced by a Taylor emf.-to-air transducer provided with a large-capacity nozzle and driven by a Hewlett-Packard signal generator. As a frequency near 1 cycle/sec. was approached, wave forms of both input and (especially) output became distorted and the limited capacity of the air relay discharge port appeared to influence the recorded response.

The above comparisons are cited to indicate the reliability of the pulse method and especially the great convenience of procuring experimental results by this technique. Chemical engineers interested in procuring dynamic response information on processing or control components and systems should consider this technique when planning experimental programs.

References

1. Hougen, J. O., Walsh, R. A., Pulse Testing Method, *Chem. Eng. Progr.*, 57, No. 3, 69-79 (1961).
2. Lees, S., Interpreting Dynamic Measurements of Physical Systems, M.I.T. Report R-128, Feb. 1957.

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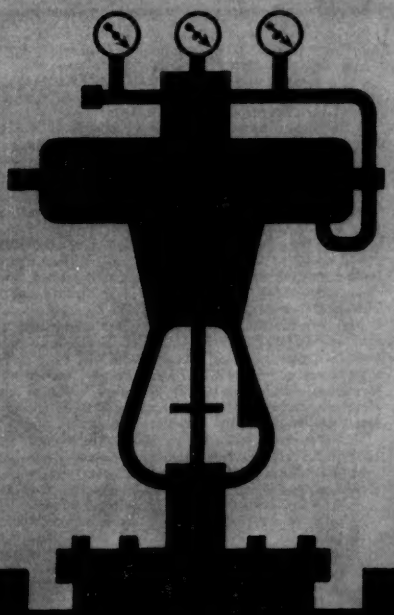
Guide Provides Useful Data for Components

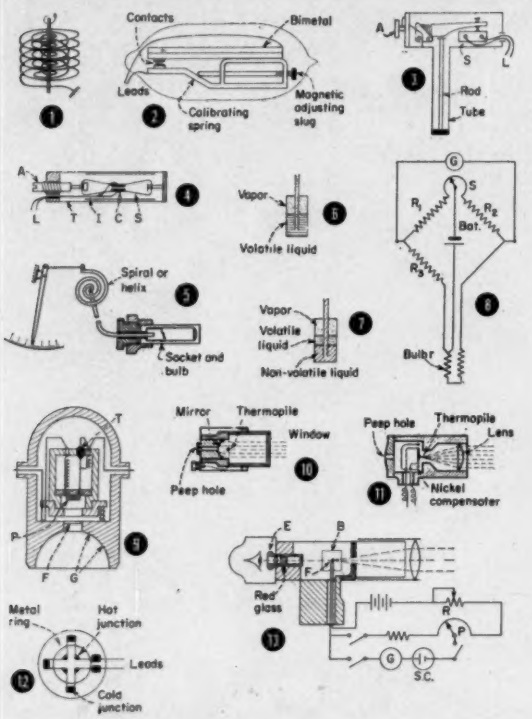
This guide attempts to compress the greatest possible amount of information into one place for the evaluation of principles and the preliminary selection of process instruments. It is an extensive revision of the similar guide that appeared as part of our June 1957 issue, and is not intended as a substitute for the literature, for manufacturers' catalogs or for their recommendations.

Many sources have contributed to the preparation of this guide, including users, manufacturers and the literature. Members of the instrument industry who supplied information are listed on p. 238.

PROCESS CONTROL



PART 2: Components



1—Temperature

(a) Differential Expansion

FIG. 1—(Weston) HIGH-EXPANSION METAL STRIP welded to low-expansion strip deflects on temperature change. Multiple layer helix tends to cancel endwise motion and leave only rotary motion when element is heated. Extra large deflection can be obtained by "coils-in-coils" construction. Range: —40 to 800 F. Accuracy: Up to 1%. Remarks: Simple, rugged, relatively accurate for temperature indication, interchangeable with glass industrial thermometers.

FIG. 2—(Edison) BIMETALLIC THERMOSTAT, hermetically sealed in glass tube that may be gas-filled. Thermostat calibrated after sealing by means of magnetic adjusting slug. Range: —10 to 600 F. Accuracy: ±4.5° F. Remarks: Continuous duty with no change in operating temperature.

Fig. 3.—(Burling Instrument Co.) Bimetallic contact-making thermostat has LOW-EXPANSION ROD in high-expansion tube that moves arm to depress switch *S* controlling circuit *L*. Set-point changed by *A* that moves pivot point of arm. Range: Subzero to 1,800 F. Accuracy: Minimum differential ¼° F. Remarks: General temperature control using electric circuit, but can be supplied with air pilot. Rugged construction, steady control, readily set control-point.

FIG. 4—(Fenwal, Inc.) Bimetallic contact-making thermostat has LOW-EXPANSION STRUTS *S* carrying contacts *C* in high-expansion tube *T*. Breakpoint regulated by temperature-set screw *A*. Opens or closes on less than 0.5° F. change. Range: —100 to 1,500 F. Accuracy: Differential less than 0.5° F. Remarks: General temperature control using electric circuit. Fast reaction time, low differential, enclosed assembly. Insulation *I* gives anticipatory action.

(b) Fluid Expansion

GENERAL: Industrial thermometers use volumetric expansion of mercury or an organic liquid such as alcohol, in non-etched glass capillary. Nitrogen fill can increase top temperature. Range: —38 to 675 F. (Hg), lower for organics, higher for nitrogen. Accuracy: Approx. 1%. Remarks: Widely used for temperatures where a record is not needed. Case protects capillary, scale readable at distance.

FIG. 5—CLASS I LIQUID-FILLED THERMAL THERMOMETER uses organic-liquid fill in bulb connected by capillary to pressure spiral or helix (like pressure gage). CLASS V is similar system but uses mercury for fill. Temperature changes at bulb distort the pressure element; new value is indicated on scale. Above approximately 25 ft. of capillary, thermometers require ambient-temperature compensation. Full compensation is obtained by second thermal system (no bulb) or, if mercury filled, by special alloy wire in capillary. Range: —200 to 1,100 F., with various fills. Accuracy: ½ to 1%. Remarks: Gives uniform scale with equal accuracy at all parts of scale. Uses small bulb. Can be supplied with short span. Capillary error compensation good for 200 ft. or more. Can be case-compensated with bimetallic compensator attached to pressure helix. Used for indicating, recording and controlling.

FIGS. 6, 7—CLASS II FILLED-SYSTEM THERMOMETER operates on vapor pressure of a volatile liquid in bulb. Interface must be in bulb, with capillary filled with the liquid (except for bulb temperatures below ambient, when capillary is vapor filled). SINGLE-FILL TYPE (Fig. 6) may lose interface. DOUBLE-FILL TYPE (Fig. 7, Bristol) has nonvolatile transmitting liquid, interface remains in bulb at all times. Range: —300 to 600 F.; 200 F. maximum for double-filled. Accuracy: ½ to 1%. Remarks: Gives high response speed, nonuniform scale; permits up to about 200 ft. of capillary without compensation. Must be calibrated for head of bulb above or below pressure element. General use for indicating, recording and controlling.

CLASS III FILLED-SYSTEM THERMOMETER has gas fill under pressure in bulb-capillary-pressure element system. Expansion of gas distorts pressure element, giving uniform scale. Range: —460 to 1,000 F. Accuracy: ½ to 1%. Remarks: Has comparatively large bulb. Ambient errors small up to 200 ft. capillary, so unit needs no compensation.

(c) Resistance Thermometers

GENERAL: All forms of resistance thermometers operate by measuring in terms of temperature the resistance of an element that varies with temperature. Measurement is ordinarily accomplished with some form of wheatstone bridge circuit.

FIG. 8—RESISTANCE THERMOMETERS are usually a coil of fine wire such as platinum, copper or nickel, wound on an insulating frame, ordinarily protected. To cancel out effect of variable-lead resistance, three-wire lead system is used. Range: —325 to 1,200 F. Accuracy: 0.25 to 1%. Remarks: Used for temperature, temperature difference and temperature averaging. Quick response, small spans possible. Can be used for highest precision.

A FINE-WIRE RESISTANCE THERMOMETER (RdF Corp.), about the size of a postage stamp, mounted in paper, phenolic resin or silicone glass. Cemented to surface to be measured. Range: —450 to 2,000 F. Remarks: Intimate bonding of resistance element to surface of object produces rapid response (less than 1 sec.) to temperature change.

THERMISTORS (Gulton Industries, Fenwal, others) are semiconductors that decrease in resistance with temperature. Can be used for very narrow spans, i.e., 4° F. Range: —50 to 600 F. Remarks: Potentially more accurate than thermocouples or resistance thermometers. Can be used as a thermocouple compensator.

(d) Thermoelectric Pyrometers

GENERAL: Thermocouples (thermoelectric pyrometers) operate on the Seebeck effect. When two wires of dissimilar metals are jointed at the ends and the junctions maintained at different temperatures, a current flows—due to absorption of heat at hot junction. Voltage produced, which is proportional to difference of hot and cold junction temperatures, is measured either by a millivoltmeter or a potentiometer calibrated in terms of temperature of the hot junction for a fixed or compensated cold-junction temperature (for potentiometers, see Section 24).

Accuracy

Unless otherwise stated, figures for accuracy, given in this guide as percent, mean that the average expected error will not be more than plus or minus that percentage of full instrument scale. Accuracy figures are difficult to obtain for many kinds of instruments. In a few cases, the figures have been estimated from best available data. It should be understood that these are rough and that well-designed instruments, well-installed and maintained, may give considerably better accuracy, while poorer results will be obtained if the reverse is true.

Since temperature measured by hot junction depends on a constant cold-junction temperature, it is customary to package the cold junction outside of the instrument case, connecting the two segments with compensating leads. Leads must be made of the same metal if base-metal couple is used, or else of metals with similar thermoelectric characteristics if Pt is used. In the instrument, variations are compensated by bimetal or nickel shunt across leads.

NOBLE-METAL COUPLES. Made of platinum and a Pt-10% Rh alloy or Pt-13% Rh alloy for highest temperatures. Top temperature depends on wire gage. Ordinarily requires protection. Range: Top temperature 2,700 F. for continuous use. Accuracy: 0.25%. Remarks: Used for high temperatures, and as a standard instrument for calibration.

BASE METAL COUPLES. Three types generally used, ordinarily with protection if in higher temperature ranges: (1) COPPER-CONSTANTAN, top temperature 700 F. depending on wire gage; (2) IRON-CONSTATAN, top temperature 1,400 F.; (3) CHROMEL-ALUMEL, top temperature 2,300 F. Range: —200 F. to temperature noted. Accuracy: Generally about 0.3 to 0.8% depending on span. Remarks: Give much higher millivoltage than Pt couples, although slightly lower accuracy. Used for same temperature range as Class I, II and V filled-system-type thermometers, as well as above and below.

FIG. 12—Special thermocouples. These include the THERMOPILE (Fig. 12, a group of thermocouples in series), which multiplies voltage by number of couples, and the VACUUM THERMOCOUPLE in which protection is afforded by sealing in evacuated glass. Remarks: Used mainly as radiation receivers in radiation pyrometers and special uses where speed or high response is needed.

(e) Radiation Pyrometers

FIXED-FOCUS TYPE. Any radiating black body gives off total radiation that depends only on the temperature. An actual body can be corrected for departure from blackbody conditions. If radiation from a definite area is focused on a thermocouple, the indicated temperature is proportional to the actual. Receipt of radiation can be made independent of distance, without focusing, by installing couple at base of long tube containing a conical and a spherical mirror. Range: 200 F. and up. Remarks: No theoretical upper temperature limit. Needs no contact with object measured. Can measure temperature of moving objects. Records on millivoltmeter or potentiometer. Readily portable, since focusing is not needed.

FIG. 9—The equivalent of a uniform-temperature enclosure is obtained by use of a gold-plated concave reflector *G*. Radiation approximating surface temperature is transmitted through fluorite window *F* and is measured by thermopile *P*. Ambient-temperature compensation is provided by thermistor *T*. (Atlantic Pyrometers.) Range: 100 to 2,400 F. Accuracy: —1 to 0.5% depending on emissivity. Remarks: Portable instrument for spot readings on surface of opaque bodies. Pyrometer measures the temperature 1/16 to 3/16 in. below surface because uniform temperature region forms under reflector *G*.

FIGS. 10, 11—FOCUSING TYPES. Similar in principle to fixed-focus type except that a mirror (Fig. 10) or a lens (Fig. 11) is used for focusing radiation onto a thermopile. Hence these types are used for permanent installations. Range: 200 F. and up. Remarks: Gives extremely fast response on fixed or moving objects, at temperatures above range of nonradiation methods.

(f) Optical Pyrometers

FIG. 13—DISAPPEARING-FILAMENT TYPE (Leeds & Northrup). Uses monochromatic radiation (rather than total radiation), determining intensity in comparison with a heated filament *F*, which disappears at corresponding temperature. Filament current is measured in terms of hot object temperature. Filament viewed at *E*. Range: 1,400 to 5,000 F. Accuracy: About 5° F. Remarks: Manually operated instrument used for indicating, not recording, high temperatures.

OPTICAL-WEDGE TYPE (Pyrometer Instrument Co.). Similar to disappearing-filament type except that target, illuminated from calibrated lamp at standard current, disappears as source intensity is varied by absorption in optical wedge. Wedge position calibrated as temperature. Standard range: 1,400 to 3,700 F. (special, to 7,500 F.). Accuracy: About 5% of temperature reading. Remarks: Manually operated instrument used for indicating, not recording, high temperatures. Any high-temperature use where hot object can be sighted.

(g) Change of State

MELTING-POINT method. Melting points of pure solids are used for thermometer calibration. Also, boiling points of pure liquids.

PYROMETRIC CONES. Calibrated ceramic mixtures molded as cones available to permit estimation of time-temperature history of fired charge. Used in ceramic manufacture.

FUSIBLE CRAYON (Tempil Corp.). Fusible crayons, each for a specific temperature, can mark hot objects to show temperature by fusing. COLOR-CHANGE PAINTS are available also, some reversible.

2—Pressure

(a) Absolute Pressure

FIG. 14—LIQUID COLUMN BAROMETER. The fundamental instrument for measuring pressure of the atmosphere. Glass tube, closed at one end and filled with mercury, is inverted in a vessel of mercury. Height of Hg column above vessel level is the barometric pressure in mm. Hg (corrected to mercury density at 32 F.). Range: Any pressure of atmosphere. Accuracy: Roughly 0.1 mm. Remarks: Although less convenient than the aneroid type, the Hg barometer is used for precise measurements and for calibration of other instruments.

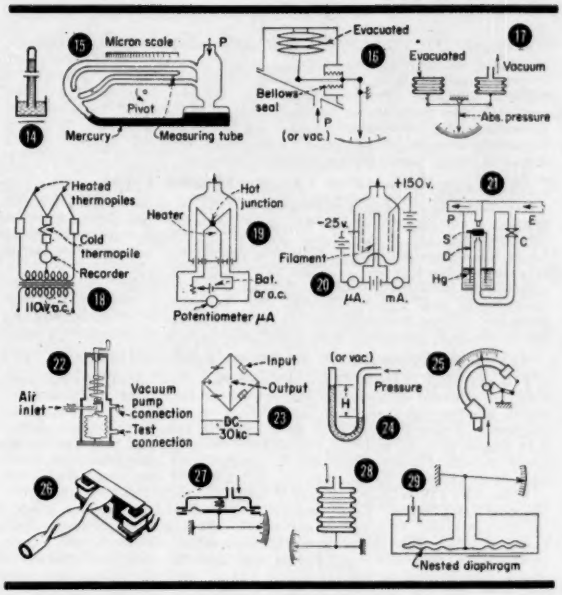


FIG. 15—McLEOD GAGE (F. J. Stokes Corp.). Gas at low absolute pressure is trapped in measuring tube by mercury as instrument rotates about a pivot through 90° from horizontal. Mercury compresses gas into top of measuring tube where final volume, expressed as initial absolute pressure, is read. Range: 0.05 to 50 mm.; 0.05 to 5,000 micron. Accuracy: ±1%. Remarks: Used as primary standard for absolute pressures in micron (0.001 mm.) range. Requires trapping of condensables to avoid error.

FIG. 16—SINGLE-BELLOWS ABSOLUTE PRESSURE GAGE (Bristol). Single evacuated bellows within vessel that contains unknown pressure transmits motion outside through bellows seal. Measurement is differential vs. vacuum, hence absolute pressure. Range: 0 to 200 mm. Hg. Accuracy: High accuracy claimed. Remarks: Can be supplied in spans as low as 0 to 6 mm. Hg for vacuum drying, steam condensers, vacuum stills, antibiotic processing.

FIG. 17—TWO-BELLOWS ABSOLUTE PRESSURE GAGE. Made with either opposed or beam-balanced bellows; one bellows evacuated, other exposed to pressure measured. Range: 0 to 25 psia. Accuracy: 1% or better. Remarks: Considered accurate for pressures down to about 5 mm. Hg. Uses are similar to above.

FIG. 18—NOBLE-METAL THERMOCOUPLES are connected in a bridge circuit (Hastings-Raydist, Inc.). Low-voltage a.c. is supplied to heated thermopiles. Unheated thermopile connected in opposite polarity provides ambient-temperature compensation. The d.c. output is measured. Range: 0 to 1,000 micron; 0.1 to 200 mm. Accuracy: High. Remarks: Rapid response, not damaged by release to atmospheric pressure. Low operating temperature, no oxidation of thermocouples. Measures total pressure as a function of thermal conductivity of the gas molecules remaining in system.

FIG. 19—THERMOCOUPLE GAGE. Inferential type, which measures thermal conductivity of gases at reduced pressure in terms of pressure. Temperature of heater filament is detected by thermocouple. Range: 1 to 200 micron (some to 1,000 micron). Remarks: Easy to use but must be calibrated for type of gas to be measured. Extends measurement below field of bellows-type gages and Hg manometers. Fast response.

PIRANI GAGE. Similar in principle to thermocouple gage, except that heated-filament temperature is measured as a resistance thermometer in wheatstone bridge. Range: 1 to 3,000 microns. Remarks: Features are similar to those of the thermocouple gage. Uses are also similar, above the operating range of ionization gages.

FIG. 20—HOT-FILAMENT IONIZATION GAGE. Uses three-element vacuum tube containing low-pressure gas to be measured. Molecules are ionized by electrons from filament; they flow to plate, are discharged, yield plate current proportional to pressure. Range: 0.001 to 1 micron. Remarks: Suitable for low absolute pressures but must be protected against burnouts if pressure goes above 1 micron. Unsuited for gases decomposed by hot filament.

FIG. 21—CARTESIAN-DIVER ABSOLUTE-PRESSURE CONTROL (Manostat Corp.). Desired absolute pressure is set inside diver *D* by opening valve *C* momentarily to system *E*. Thereafter *D* closes seat *S* against nozzle *N* connected to pump *P*, unless system's pressure changes. Range: Holds pressures from 1 mm. to 100 psia. Accuracy: 0.1% of set point. Remarks: Simple device maintains desired pressure or vacuum. Made in glass or metal. Readily reset to other pressures.

FIG. 22—ANEROID MANOSTAT (Wallace & Tiernan). Evacuated bellows, permanently sealed, provide zero absolute pressure reference. Temperature-compensated spring opposes bellows compression. Range: 0.8 to 60 in. (Hg) abs. Accuracy: High. Remarks: Dead-end service in static testing systems. Also used in calibration and testing.

FIG. 23—MICROMANOMETER (Consolidated Electrodynamics). One plate in electrical condenser is pressure-actuated diaphragm. Condenser forms one arm of capacitance bridge that can be adjusted to balanced condition. Pressure differential deflects diaphram from other electrode, thus unbalancing circuit. Bridge is restored to balance by d.c. voltage that exerts electrostatic force to oppose diaphragm movement. Magnitude of restoring voltage is a measure of pressure. Range: 1 to 150 micron absolute. Accuracy: ± 1% at 100 micron.

(b) Gage Pressure or Vacuum (Liquid Type)

FIG. 24—Liquid-filled glass columns of WELL- or U-TYBE DESIGN measure pressure, draft or vacuum vs. pressure of atmosphere. Pressure proportional to *H*. Range: About 2 in. of liquid head. Accuracy: About 0.1 in. of manometer liquid. Remarks: Simple and accurate, but limited by glass construction and available column height.

INCLINED-DRAFT GAGE. Similar to U-tube, but this has one inclined leg and a large-diameter well to increase reading accuracy. Accuracy: Better than 0.01 in. of liquid. Remarks: Used chiefly for low drafts and pressures where visual indication is sufficient.

(c) Gage Pressure or Vacuum (Spring-balanced Type)

FIG. 25—BOURDON-TYPE PRESSURE-DEFLECTING UNITS. Tube of flattened cross-section, shaped to an incomplete circle (conventional bourdon) or spiral or helix, tends to straighten with pressure increase. Motion is multiplied to pointer by cam or gearing. Range: 0 to 10,000 psia. or higher. Accuracy: ½%. Remarks: Most indicating gages use conventional bourdon. Simple, reliable and usually accurate. Cam type (Helicoid Gage) has no backlash, can use suppressed scale.

FIG. 26—TWISTED-TUBE PRESSURE ELEMENT (Daystrom-Wiancko) is a hollow tubing that has been flattened and twisted about a longitudinal axis. One end is sealed, the other open to pressure. Tube responds to pressure or vacuum applied internally or externally, or to pressure difference between internal and external values. Pressure response is converted to electric signal. Small internal volume, low mass and high stiffness give the element a maximum natural frequency of 10,000 cps. Small rotational movement of element keeps stresses below static limit. Hence, hysteresis is minimum.

FIG. 27—SLACK-DIAPHRAGM GAGE. Slack diaphragm is balanced by pressure or tension of a calibrated spring. Range: 0 to 120 in. water column (w.c.). Accuracy: About 1%. Remarks: Used especially for low pressure and draft such as 0 to 0.5 in. w.c.

FIG. 28—BELLOWS-TYPE GAGES include metallic bellows, capsular and multiple-diaphragm units, in which pressure is balanced against unit's spring action or against a calibrated spring. Range: Vacuum to about 100 psi. Accuracy: ½ to 1%. Remarks: Simple and rugged, widely used in moderate-pressure and vacuum instruments, especially in recorders.

FIG. 29—NESTED-DIAPHRAGM GAGE (U.S. Gauge). A variation of the bellows type (Fig. 28). Range: 30 in. w.c. to 30 psi. Accuracy: 1%. Remarks: Gage withstands high external overpressure without damage.

FIG. 30—HIGH-TEMPERATURE PRESSURE PROBE (Manning, Maxwell & Moore). All-welded unit with diaphragm capsule and capillary tubing filled with Na-K alloy. Temperature-compensated by relatively limp diaphragm capsule. Capillary is connected to conventional bourdon-type gage. Range: 0-400 psig. at temperatures up to 1,450 F. Accuracy: 1%/1,000 F. Remarks: For nuclear reactor and high-temperature applications in liquid metals.

FIG. 31—STAINLESS STEEL BELLOWS (MSA Research Corp.) senses pressure in liquid metal. Core of the variable transformer is directly connected to the bellows. Variations in pressure are translated into an electrical output, which is indicated by a suitable meter or recorder. Remarks: Unit directly measures pressure of molten metal. Pressure range of gage is adjusted by linkage in balancing spring. Transformer windings of transmitter and receiver are connected in series, thus providing voltage and temperature compensation.

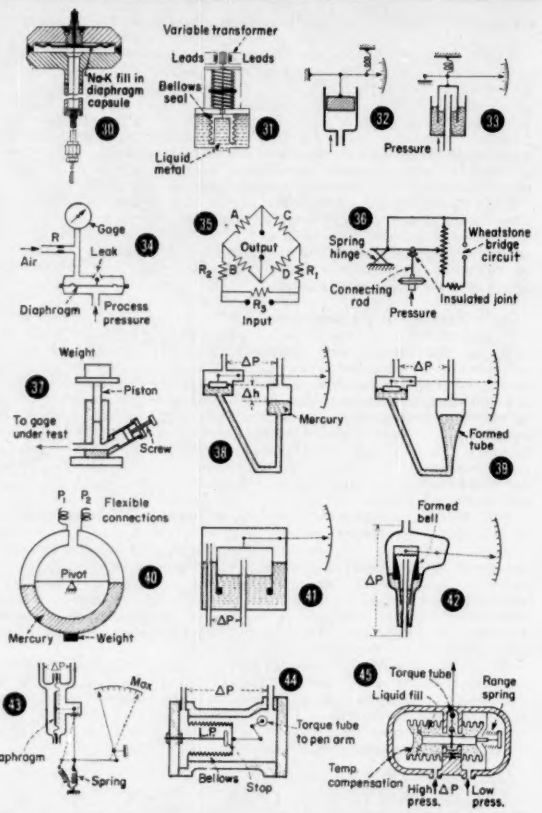
FIG. 32—PISTON GAGE. Except for its friction, unit is comparable to slack-diaphragm gage. Pressure is balanced by a calibrated spring. Range: Vacuum to high, depending on spring. Remarks: Used mainly for study of pressure cycles, as in the steam engine indicator. Operates stylus, records.

FIG. 33—LIQUID-SEALED BELL. Inverted bell dips into liquid, which acts merely as a seal. Bell is balanced by a calibrated spring. Range: Vacuum to about 15 in. w.c. Accuracy: 1% or better. Remarks: Used for low pressures and vacuums; can be made extremely sensitive.

FIG. 34—FORCE-BALANCE GAGE SEAL (Bristol). Process pressure is applied to a force-balance pneumatic transmitter; transmitter pressure then activates gage. Restriction *R* in air supply line, combined with diaphragm-controlled leak vent, exactly duplicates pressure. Range: Any. Accuracy: 1%. Remarks: Gage segment may either be built into the rest of the unit, or separated from it by as much as 1,000 ft. for remote control. Either way, gage is protected against corrosive, viscous, dirty or radioactive fluids.

FIG. 35—STRAIN GAGE LOAD CELL (Baldwin-Lima-Hamilton Corp.). Uses small resistance elements bonded to an element that expands under internal pressure. Stretch increases resistance, which is proportional to strain. Usual method assembles four elements in a wheatstone bridge so that resistances *A* and *D* are strained, *B* and *C* are not. Other resistances are provided for temperature compensation and calibration. Range: Unlimited. Accuracy: ¼% or better. Remarks: Relatively new method, becoming popular owing to high accuracy, ease of transmission to millivoltmeter or potentiometer indicator or recorder, good linearity and reproducibility, negligible hysteresis, quick response. Unbonded types also used.

FIG. 36—RESISTANCE PRESSURE DETECTOR (Edison) converts gage pressure to an electrical resistance by means of capsule (shown) or bourdon tube. Connecting rod positions a noble-metal contact wiper over precision potentiometer. Range: 0-1½ to 0-5,000 psig. Accuracy: ±0.75 to ±2%. Remarks: Internal volume of capsule 0.29 cu. in.; of bourdon tube, 0.15 cu. in. Response speed 50 milliseconds full scale.



(d) Gage Pressure or Vacuum (Weight-Balanced Type)

FIG. 37—DEADWEIGHT TESTER. Type of piston gage in which test pressure is balanced against known weight when applied to known piston area. Pressure is applied by secondary piston and screw. Weight platform is rotated to avoid sticking. Range: Unlimited. Accuracy: 0.1%. Remarks: Used as primary standard for calibration of gages.

(e) Differential Pressure (Manometer Type)

GLASS LIQUID-COLUMN MANOMETERS. Identical with those in Section 2 (b) except that the two pressures are connected, one to each end of the tube. Accuracy: About 0.01 in. of manometer liquid. Remarks: Simple and accurate but limited by glass construction and available column height. Limited static pressure.

FIG. 38—METAL MANOMETERS, PLAIN TUBE. Liquid level, usually mercury, is read by carrying float position outside manometer by pressure-tight bearing, torque tube or magnetic follower. Range: Differentials of 10 in w.c. minimum to 400 in. or higher. Accuracy: 1% Remarks: Most common method of measurement for rate-of-flow meters. Also for differential-pressure level and density measurements. Static pressures to 5,000 psi.

FIG. 39—METAL MANOMETERS, FORMED TUBE. Similar to plain tube type except that range tube is formed to variable parabolic cross section to extract square root for flow. Accuracy: 1%. Remarks: Not commonly used, due to expense of accurately forming the range tube. Gives uniform scale for flow.

TILTING MANOMETER. Manometer balanced on knife edge, and connected by flexible leads to pressure sources, tilts in proportion to differential. By use of cam and counterweight (Cochrane), tilt can be made directly proportional to flow. Range: About 10 in. w.c. maximum. Accuracy: 1-2%. Remarks: Used for general rate-of-flow measurement. Avoids need for pressure-tight shaft.

FIG. 40—RING-BALANCE MANOMETER. Similar in principle to tilting manometer. Split tubular ring with flexible leads rotates about central knife edge, balanced by a weight. Range: About 10 in. w.c. max.

Accuracy: 1%. Remarks: Used for general rate-of-flow measurement. Avoids need for pressure-tight shaft.

(f) Differential Pressure (Sealed-Bell Type)

FIG. 41—FLOATING BELL, single. Similar to single-pressure bell, Section 2 (c), except enclosed for application of pressure to both sides. Bell position proportional to differential, carried outside by torque tube or pressure-tight bearing. Range: 0.2 to 12 in. w.c. Accuracy: 1%. Remarks: Large area of bell gives ample power for operating recording mechanism at very low differentials.

FIG. 42—FORMED BELL (Bailey Ledoux bell). Bell shaped internally to parabolic form extracts square root of differential to give uniform scale on flow. Hg seal. Range: 212 in. w.c. max. differential. Accuracy: 2% actual flow. Remarks: Used for general rate-of-flow metering. Uniform scale facilitates reading and integrating.

(g) Other

FIG. 43—SLACK DIAPHRAGM, SQUARE-ROOT COMPENSATED (Hays Corp.). Addition of calibrating spring in line with motion arm (see sketch) extracts square root for flow. Range: Min. 0.2 to max. 120 in. w.c. differential. Accuracy: 1 to 2%. Remarks: Measures flow for low differential where uniformly divided scale is desired.

FIG. 44—SINGLE-BELLOWS DIFFERENTIAL GAGE. Bellows (or diaphragm) in casing is subjected to low pressure on one side, high on the other. Bellows extension measures differential. Usually provided with calibrating spring for ranging. Range: Min. 25 to max. 800 in. w.c. differential. Accuracy: About 2%. Remarks: Simple and rugged. Range easily changed. Requires no mercury. Minimizes maintenance. General differential pressure use.

FIG. 45—DOUBLE-BELLOWS DIFFERENTIAL GAGE (Barton Instrument Corp.). Opposed bellows in two-part casing are filled with liquid, balanced by a spring and connected together by a shaft passing through a restriction. Arrangement acts like spring-balanced piston with high pressure at one end, low at other. Pulsations damped by valve controlling the flow of liquid from one bellows to the other. Temperature compensation for liquid expansion provided by floating bellows section. Range: 0-10 in. w.c., 0-400 psi. Accuracy: 0.5% of full differential. Remarks: Unharmed by over-ranging. Range easily adjusted. No mercury. Torque tube for transmitting motion eliminates possible leakage.

3—Force, Tension, Compression

FLUID PRESSURE-SPRING SYSTEMS. Most pressure-measuring systems in Section 2 can be used for force measurement. Particularly these include spring-balanced devices of Section 2(c). Bellows, diaphragms and capsular elements are commonly used, consisting of two expansible elements coupled by tubing, with the system liquid-filled. Force on one element is transmitted to the other and is indicated there as a deflection. Transmitter is usually a stiff spring unit; receiver, a bourdon type. Range: Unlimited. Accuracy: 1% or better. Remarks: Units require calibration, but some can be rugged. Indication can be transmitted over several hundred feet.

PNEUMATIC FORCE BALANCE. Force-balance systems as in Section 25(b) or Fig. 34 balance a force (or a pressure) on one side of a diaphragm against pneumatic pressure on the other, transmitting latter pressure to a pressure indicator. Range: Moderate force magnitude. Accuracy: 0.5% or better. Remarks: Useful where a null system with virtually no displacement of the measuring diaphragm is desired. Can transmit reasonably long distances.

FIG. 35—BONDED STRAIN GAGES [see section 2(c)]. Same strain-gage units used for measuring elongation (strain) of pressure-sensitive element can be used to measure strains produced by tension, compression, weight, etc. Either four resistance elements in a bridge circuit, or just two (one a dummy for temperature compensation), are bonded to strained surface and resistance change is measured. Range: Unlimited. Accuracy: Strains as small as 0.000001 in. can be measured. Remarks: Strain gages are available mounted on paper, fabric or plastic that is bonded to strained surface by cement; or load-measuring units incorporating already-bonded gages are available for measuring weight, force, deflection, motor load, etc.

UNBONDED STRAIN GAGES. Unit consists of two rigid frames laced with four calibrated resistance elements in bridge circuit. Strain tends to pull frame members apart, increasing strain in one pair, reducing strain in second pair of elements. Range: Forces to about 4 lb., for displacements to about 0.002 in. Remarks: Less used than bonded type. Affords easy method of measuring small strains from ½-oz. to 4 lb., or for building into instruments. Temperature compensated.

4—Radioactivity Measurements (Applications, see Sections 6 to 9)

GEIGER-MUELLER COUNTER. Metal cylinder, with central grounded electrode, is filled with inert gas such as argon. Window of aluminum alloy or suitable nonmetal admits radioactive particles or rays. With electrode charged to 1,000-1,200 v., each particle entering causes ionization, and momentary conduction, which is amplified and fed to pulse-counting electronic circuit. Counting can be speeded with lower pulse strength by lower voltage—then called PROPORTIONAL COUNTER. Detects alpha, beta or gamma radiation. Used in monitors, X-ray diffraction, level and thickness gages.

IONIZATION CHAMBER. Similar to Geiger, but uses low voltage to give minute current proportional to total radiation received. Used in health monitoring, thickness gages.

SCINTILLATION COUNTER. Radiation (alpha, beta, gamma and X-rays, and neutrons) strikes phosphor such as zinc sulphide, giving off light flashes that are detected and amplified by photomultiplier tube. Output amplified, fed to pulse counter. Used for general radiation detection and measurement in nuclear laboratories.

PHOTON DETECTOR (Bendix Corp.). Array of Alnico magnets produces uniform magnetic field of 400 gauss, perpendicular to the electric field. Special high-resistance coatings, applied to glass substrates, give field and dynode strips. Anode is stainless steel; cathode, tungsten. High voltage (2,000 v. d.c.) provides potential gradient across the dynode and field strips. Electrons enter through transparent metallic grid and generate secondary electrons in each dynode strip. Current gain is 10^7. Range: 0.2 to 150 millimicron. Remarks: For detection in ultraviolet spectrography, X-ray spectrography, nuclear radiation and high-altitude solar radiation.

NEUTRON-FLUX DETECTORS. There are three main types: (1) BORON-TRIFLUORIDE PROPORTIONAL COUNTER is high-voltage ionization chamber with tungsten electrode and BF_3 gas inside. Each boron disintegration due to a neutron causes a pulse at collecting electrode. (2) FISSION CHAMBER has electrodes coated with enriched uranium oxide. Each neutron capture causing U-235 fission gives off heavy particles, ionizes gas. (3) BORON-LINED IONIZATION CHAMBER can compensate for gamma radiation by negative-d.c. bias on chamber, a.c. operating voltage.

ATOMIC BATTERY (Ohmart Corp.) generates current directly from gamma radiation, requiring no high-voltage source and only one vacuum tube for amplification. Accuracy: 2 to 3%. Remarks: Used for dosimeters, monitors, level gages.

SCALERS AND PULSE COUNTERS. Electronic amplifying and registering devices employ trigger circuits to record on lights or mechanical counters, scaling down actual counts by factor of 2 or 10. Integrates pulses over a period of time. Also of this type are PULSE-RATE METERS, used primarily for graphic recording, or printed digital record (Streeter-Amet).

5—Fluid Flow

(a) Volumetric Meters

PISTON METER. A piston driven by fluid pressure shuttles back and forth, recording the number of strokes it makes in terms of volume it passes. Variations include multiple pistons driving a wobble plate; double piston in two-part cylinder; and reciprocating-bellows type (used for gas). Piston motion operates poppet or surface-type valves. Range: Up to 1,500 gal./min. Accuracy: 1% or better, depending on type. Remarks: Gives volumetric measure of flow. Some types automatically correct for temperature variations. Generally handles wide range of viscosities. Most commonly used with liquids (except for fuel-gas meters).

METERING PUMPS. Liquids may be metered by many kinds of positive-displacement, constant-speed pumps, such as piston-type proportioning pumps, piston-type rayon-spinning pumps, gear pumps. Range: Low to moderate. Accuracy: High. Remarks: This type accurately reports the rate of liquid delivery either in discrete increments or in pulsationless flow. Can be provided with remote recording or indicating counter.

FIG. 46—LOBED-ROTOR METER. Two lobed impellers rotate in a close-fitting chamber by the action of timing gears, contacting neither the chamber wall nor each other. Movement is similar to that of a gear pump, with liquid or gas carrying around the outer ends of chamber. Range: Up to about 1 million cu. ft./hr. Accuracy: Variable, depending on the slip. Remarks: Used chiefly for gases, but can take clean liquids. Low pressure drop. Slip increases at low flow rates, so unit is best used at higher rates.

FIG. 47—NUTATING-DISK METER. Circular disk in a spherical, cone-bounded chamber is cut by a vertical partition between inlet and discharge points. Spaces above and below disk create three or more separate chambers that progress from inlet to discharge side as disk nutates with volume of liquid passing through meter. End of axis rotates, drives counter. Range: 1 to 1,000 gal./min. Accuracy: 1% or better. Remarks: This unit meters the widest range of corrosive and noncorrosive industrial liquids, including domestic water. Available for high viscosities or pressures. Some units have automatic shutoff for batching.

FIG. 48—ROTARY-VANE METER. Eccentric drum carries radial vanes that have been forced outward by springs against the meter casing to form sealed pockets. Fluid pressure rotates drum. Range: Moderate. Accuracy: ½% or better. Remarks: Can be used for liquids or gases. Has virtually no clearance except at ends, so slip is slight.

FIG. 49—LIQUID-SEALED GAS METER. Cylindrical casing, more than half full of water, contains drum with four "spiral" vanes and gas inlet at center. Gas enters upper compartments, forcing rotation. Range: Wide range, from few cu. ft./min. to large size. Accuracy: 0.5% or better. Remarks: Used both for metering fuel gas and for calibrating other meters. Pressure drop as low as 0.1 in. water column.

(b) Variable Head Meters (Closed Channel)

GENERAL: Variable-head meters produce either: (a) differential pressure head if meter is closed-channel type, or (b) elevation of level behind an obstruction if unit is open-channeled. Results in the first type are therefore measured by various forms of differential-pressure measuring devices described in Sections 2 (e), (f) and (g); while results in the second type are monitored by level-measuring devices (see Section 6). In neither case does flow vary directly with the quantity measured; hence, correcting means are often applied to give linear flow scales—e.g., Figs. 39, 42, 43 and 219.

Meters tabulated in this section are rate-of-flow meters. For totalized flow over a period of time, they can be provided with integrators or their charts can be planimetered. In meters without linear-flow-scale correction,

the integrator supplies the correction by means of a cam, adding units to a counter at equal time intervals in proportion to the existing flow rate.

A simple method of electrical integration is used in the resistance manometer (Republic Flow Meters Co.) shown in Fig. 219. Height of the mercury determines number of resistance elements to be linked in series with the manometer output. Elements are arranged so that current output is directly proportional to flow rate. Hence, an electrical power integrator similar to a watt-hour meter can be used to integrate the flow.

Meters for compressible fluids are sometimes automatically corrected for static pressure variations, or a static pressure pen records simultaneously on the same chart.

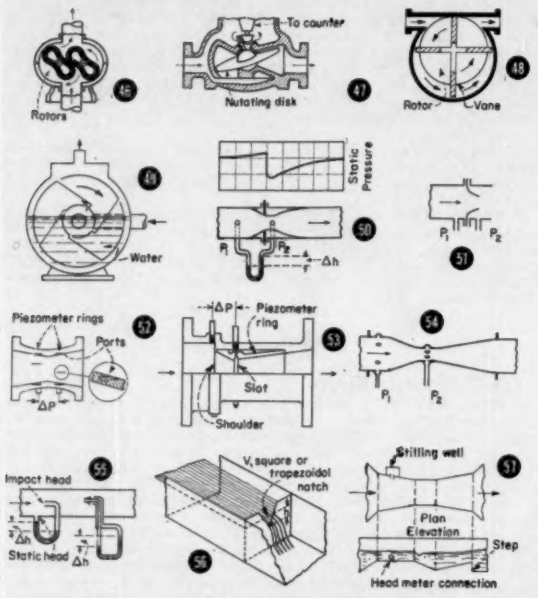


FIG. 50—ORIFICES. Built-in pipeline constriction gives a reproducible—and in some cases, predictable—pressure drop across the constriction for various rates of flow. Commonest type is the square-edged orifice in a thin plate. Such orifices are usually concentric, but may be segmental or eccentric. Pressure connections can be made close to the orifice but are usually at a point well upstream and at point of maximum contraction for maximum differential and most accurate predictability. Practically all differential measuring devices in Sections 2 (e), (f) and (g) are used. Accuracy: High but variable. Remarks: Orifice characteristics are well known and predictable. Orifices are relatively cheap but have rather high permanent pressure loss. Accuracy depends on care in construction and installation.

FIG. 51—FLOW NOZZLE and VENTURI NOZZLE. The first (see sketch) is a streamlined orifice; the second, a venturi tube (see below) designed for installation inside a pipe. As restrictions, both produce a pressure drop varying with flow rate. Range: Moderate sizes. Accuracy: Good. Remarks: More expensive than plate orifices, but have lower permanent pressure loss.

FIG. 52—FLOW TUBE (Gentile, Foster Engineering Div.). Streamlined restriction tube, flanged for installation in pipeline, has ports almost parallel to pipe opening in both up- and downstream slopes to piezometer-ring pressure connections. Range: All commercial sizes. Accuracy: High. Remarks: Gives negligible permanent pressure loss. Shorter and easier to install than most venturi-type differential producers.

FIG. 53—FLOW TUBE (Dall, B-I-F Industries). Streamlined restriction tube with abrupt decrease followed by further conical restriction and rapid recovery section. Annular gap averages the pressure at throat for solids-free liquids; special design for suspended solids. Range: 31,000 gal./min. Accuracy: ±1%. Remarks: Used for gas, air, water, process fluids, sewage, wastes. Claimed to give lowest permanent loss of any differential producer.

FIG. 54—VENTURI TUBE. Streamlined differential producer, with practically unity flow coefficient, has 20° entrance cone and 5-6° discharge cone for maximum pressure recovery. Pressure openings connect to piezometer rings at the throat and the entrance. Range: 2 in. and up. Accuracy: 1%. Remarks: Used mainly for large flow of water, process fluids, wastes, gases. Gives second-smallest permanent pressure lost of any differential producer.

FIG. 55—PITOT TUBE. Measures difference between impact and static pressures in a fluid flowing through a closed duct. This static-pressure difference is proportional to velocity head ($V^2/2g$), and hence gives fluid velocity at a point. With velocity traverse, flow rate can be approximated by using average velocity across duct. Range: Unlimited. Accuracy: Variable. Remarks: Simple device; easily installed; operable in very large ducts. Since its flow coefficient cannot be predicted accurately, it must be calibrated.

(c) Variable Head Meters (Open Channel)

FIG. 56—WEIRS. Any obstruction in an open channel causes a backing-up of flowing liquid. Degree of backup depends on flow rate, and can be calibrated in terms of head vs. flow rate. Several predictable forms of obstruction (weirs) have been developed, including the V, square and trapezoidal-notch, all of which are cut from plate metal according to proportions that give predictable formulas. Range: Very large. Accuracy: Fair. Best results need calibration. Remarks: Used mainly for measuring large flows of water, sewage or wastes. Usually constructed on the job.

FIG. 57—FLUMES are flow channels with gradual rather than sharp restrictions. Flow rate varies with head of quiet water behind the restriction, compared with bottom height at restriction. Type shown is Parshall flume. Discharge is determined from empirical formula. Range: Larger than weirs. Accuracy: Variable. Remarks: Used mainly for measuring large flows of water, sewage or wastes. Constructed from published dimensions on the job. (See Parshall, Trans. ASCE, 1926.)

(d) Variable-Area Meters

GENERAL: In variable-head meters, the restriction remains constant while the pressure differential is allowed to vary with flow rate. In variable-area meters, differential is maintained constant but flow area at the point of restriction is allowed to vary with flow rate. Several methods are used, some of which are affected by variations in viscosity. The commonest type is the rotameter, which can be designed to operate relatively independently of viscosity.

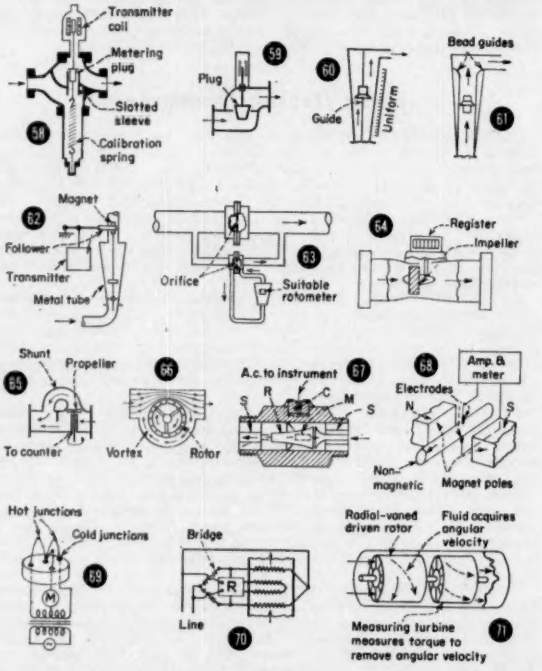


FIG. 58—PLUGGED- AND-PORTED CYLINDER (Bailey Meter Co.). Cylindrical plug, loaded by a weight or calibrated spring, moves in sleeve containing rectangular slots. Lift is directly proportional to flow rate. Similar idea (Brown) has rectangular orifice, also makes the lift directly proportional to flow. Range: 1 to 4-in. iron pipe size. Accuracy: Sensitivity is ¼%. Remarks: Used for oils and clear liquids, especially for liquids of relatively high viscosity.

FIG. 59—TAPERED-PLUG ORIFICE. With flow against the smaller diameter of the plug, plug rises until upward fluid force balances downward force of gravity. Brooks uses this type in a high-pressure indicator with magnetic follower. Range: Moderate. Remarks: Sensitive to changes in viscosity.

PLUG FLOW INDICATOR. Gems Co. makes a flow indicator similar to a lift-plug check valve, but in which the flow against plug's bottom lifts plug, actuates a magnetically operated switch. Range: ⅛ to 3 in.

Accuracy: Flow over 1.5 gal./min. Remarks: Does not meter; indicates flow or lack of it. Switch operates warning light.

TAPERED-TUBE ROTAMETER, FREE BOB. This is the earliest type of rotameter, using a top-shaped bob with sloped flutes in the bob to induce rotation, thus centering bob in tube. Tube is of glass, tapered uniformly and placed vertically. Upward flow causes bob to seek equilibrium level proportional to flow, i.e., where pressure drop equals gravity pull. Range: ⅛- to 4-in. diameter. Accuracy: ½ to 2%. Remarks: This type is now often superseded in favor of types with guided bobs or bobs insensitive to viscosity.

FIG. 60—TAPERED-TUBE ROTAMETER, CENTER GUIDE. Common type where position of bob is to be indicated on an external scale by direct movement of pointer or by electrical transmission. Inductance bridge as described in Section 25(c) is often used for transmission. Can readily be equipped with electronic, induction or mercury-switch alarm. Range: ⅛- to 4-in. diameter. Accuracy: ½ to 2%. Remarks: Used where visual reading of float level is impractical (opaque liquids), or where transmission is required. Permits the use of viscosity-immune bobs for rate of flow indication.

FIG. 61—TAPERED-TUBE ROTAMETER, BEADED TUBE. Commonly used for visual-reading rotameters. Tapered glass tube contains three internal beads of constant internal diameter that guide the bob. Taper between beads serves as variable-area section. Range: 4 in. maximum. Accuracy: ½ to 2%. Remarks: Used for stability of bobs in visual-reading meters. Enables viscosity-immune bobs to be used without center guide.

FIG. 62—TAPERED-TUBE ROTAMETER, METALLIC (Fischer & Porter Co.). Use of magnetic follower and pneumatic or electric transmitter [see Section 25(b)] enables use of short metal tapered tube. Accuracy: High. Remarks: Can handle fluids at high pressure, as well as high temperature, with consistently high accuracy.

FIG. 63—KINETIC MANOMETER/ROTAMETER (Fischer & Porter). Orifice or other differential producer is bypassed with a rotameter to give about half the pressure drop through each. Rotameter flow is proportional to main-line flow. Remarks: Enables a rotameter to be used for larger than normal flows.

(e) Velocity and Current Meters

CUP ANEMOMETER. Hollow hemispheres, mounted radially to form wheel-like spokes, create a simple sort of current meter. Air current catches open side of cups, producing a rotation speed proportional to air velocity. Remarks: Used mainly for wind velocity rather than flow rate.

VANE-TYPE VELOCITY METER (Illinois Testing Laboratories). Impact of a gas when blown against a vane moves the latter against a hair spring. Used in open air, or with special jet tubes in ducts or restricted locations. Range: 20 to 24,000 ft./min. Accuracy: 3%. Remarks: Used mainly in heating, ventilation, air-conditioning and exhaust systems.

FIG 64—CURRENT METERS (B-I-F Industries). Turbine wheel in a venturi-shaped tube, installed in pipeline, rotates at rate proportional to flow rate, driving integrating counter. Range: 2 to 36-in. pipe size. Accuracy: 2% of actual flow. Remarks: Gives low pressure drop. Used for liquids only. Can stand high temporary overloads. Subtracts reverse flow.

FIG. 65—SHUNT-TYPE CURRENT METER (B-I-F Industries). Tube with segmental orifice and bypass loop is installed in flow line. Turbine wheel at entrance of shunt measures fixed proportion of main flow, totalizes by magnetic-drive counter. Range: 1- to 14-in. main pipe size. Accuracy: 2% of actual flow. Remarks: Used for steam, gas or air only (no liquids). Easy to install and to change orifice for capacity change. Magnetic-counter drive eliminates stuffing box.

FIG. 66—VORTEX METER (Rotron Controls). Cylindrical flow path with semicylindrical bulge in side produces a swirling vortex. Light "vortex cage," placed in the position shown, operates the counter by rotating at a velocity proportional to flow rate. Range: 10-21,000 gal./min.; 10-3,100 million cu. ft./day. Accuray: ½%. Remarks: Virtually no mechanical friction. Unit can be used for nonlubricating as well as lubricating liquids. Also suitable as a gas flowmeter and with density compensation as a gas mass flowmeter.

FIG. 67—ELECTRIC CURRENT METER (Potter Aeronautical Corp.). Turbine wheel *R*, mounted between straightening vanes *S* in cylindrical passage, is core-shaped to give venturi-like flow, causing end-thrust balance to reduce friction. Rotor *R* contains magnet *M*. Rotating field generates a.c. in coil *C* for flow-rate indications. Readings may be combined with density correction for mass flow [Section 5(f)]. Range: ⅛- to 12-in. pipe size. Accuracy: ±½%. Remarks: Elimination of end thrust is said to give high accuracy. Meter has little pressure drop. Good for static pressures to 20,000 psi., temperatures to 1,200 F., flow rates from 0.1 to 12,000 gal./min.

FIG. 68—INDUCED-VOLTAGE ELECTROMAGNETIC FLOWMETER (Fischer & Porter, Hays, others). Liquid flowing through a nonmagnetic tube with an internal nonconducting coating in a magnetic field induces a voltage in fluid. Voltage is proportional to flow rate and field intensity. Electrodes, sealed in tube, conduct the output to amplifier and flow-rate meter. MSA Research welds electrodes to the outside of the tube and uses permanent magnet for source. This type is used for liquid metals to 1,500 F. Range: Any size pipe, velocity from 0.3 to 30 ft./sec. Accuracy: ½ to 1%. Remarks: No pressure drop except straight-line loss. Accuracy unaffected by pressure, viscosity, density or character of flow. Response is linear. Liquid must be slightly conducting.

FIG. 69—HOT-WIRE ANEMOMETER. Various types; type sketched (Hastings-Raydist) uses thermopile heated by a.c. Unit is cooled by flow; degree of cooling is proportional to local flow velocity, is measured as d.c. output of thermopile by millivoltmeter. Range: 0 to 20,000 ft./min. of air. Accuracy: 2-5%. Remarks: Used mainly as a directional or nondirectional air-velocity meter, but can be enclosed [Section 5(f)] for use as a mass flowmeter.

(f) Mass Meters

GENERAL: Mass meters are designed to measure mass flow rate rather than volume flow rate or velocity. If discrete increments are weighed by an automatic scale-balanced tank that cuts off at set point before discharging the increment to be weighed, then the operation is semicontinuous. However, unit can also be used for batching and for mass-flow totalizing. No temperature correction required.

Many types of volumetric, differential-pressure and velocity flowmeters can be modified to incorporate a density correction automatically; hence to indicate mass flow rate. This has been done with piston meters, head meters (especially for gases but also for liquids), and velocity meters (i.e., the Potter meter of Fig. 67 and electromagnetic meters of Fig. 68).

True-mass flowmeters, which measure mass directly without a density correction, are of two general types: (a) those in which either heat or a substance whose concentration can be detected is added to the flow (e.g. dyes, salts or radioactive tracers); and (b) meters that impart angular momentum to the flowing fluid and measure the torque required to do so.

FIG. 70—HEAT-ADDITION FLOWMETER. If known heat is added to unknown flow of a fluid whose specific heat is known, temperature rise is inversely proportional to mass flow rate. Type shown (Cutler-Hammer) varies electric-current flow to heater for fixed temperature rise, using resistance thermometers in bridge to regulate heat addition. Current flow is proportional to fluid flow. Range: Theoretically unlimited. Remarks: Used in gas metering for large flows. Another type has been used for liquid metering.

FIG. 71—ANGULAR-MOMENTUM METER (General Electric, Inertial Instruments, others). Meters of this type have a cylindrical body containing two radially vaned rotors. The first is rotated at constant speed to impart angular acceleration to the fluid. The second is restrained either electronically or by a spring, and measurement is made of the torque required to remove the angular momentum put in by the first rotor. Torque is proportional to mass flow rate. Range: 1 to 15 lb./sec. Accuracy: 1% of point at 5-to-1 flow range. Remarks: One type (Inertial Instruments) can be used on fluids from 0.2 to 1.5 specific gravity, 0.1 to 25 centipoises, temperatures from —67 F. to 250 F. Weighs only 6 lb. Designed for liquids or gases. Has either analog or digital output.

GAS MASS FLOWMETER (Rotron) combines Vortex volumetric meter, shown in Fig. 66, with gas-density meter (see Section 11, Fig. 122). Combination can compute the product of flow and density readings. Range: 300 to 6 million lb./hr. Accuracy: ±1%.

6—Liquid Level

(a) Float Methods

GAGE GLASSES. Common method for visual observation, showing actual level. Many special types operate at high pressures, low temperatures, etc. Range: Limited only by tank height. Accuracy: About 0.02 in. Remarks: Where applicable, this is the simplest and most direct method for level measurement.

FIG. 72—TANK FLOAT with external indicator. Many types available. Level changes can be reproduced same size as actual changes, or magnified or reduced. Properly-weighted floats indicate the interface level between immiscible liquids. Range: Limited only by tank height. Accuracy: About 0.02 in. Remarks: Commonest method of indirect level indication. Simple, reliable. Introduces problems in pressure tank, but can be handled with various transmissions (e.g., see Fig. 214). Fischer & Porter makes float gage with magnetic follower. Gems Co. makes level alarm on same principle.

FIG. 73—FLOAT-CONTROLLED VALVE. With or without intervening pilot, float can open or close inlet or outlet valve. Range: Unlimited. Accuracy: Variable. Remarks: Commonest method of level control.

FIG. 74—MAGNETIC GAGE (Jerguson). Guided float contains actuating magnet that causes edge-magnetized wafers on indicator to rotate 180°. Number of wafers rotated indicates liquid level. Remarks: Chamber made of Type 304 stainless steel, float, of Type 321; both are nonmagnetic. Permits direct level measurement up to 10,000 psi. and 800 F.

FIG. 75—MAGNETIC POSITION-CONVERTER (Brooks Instrument Co.) translates linear motion of float into rotary motion. Magnet in float attracts leading edge of helix, causing rotation of pointer. Accuracy: Responds to 0.25% change in float position. Remarks: Can be used up to 40,000 psi. and 800 F.

FIG. 76—BUOYANCY DISPLACERS. Buoyancy of displacer, held at substantially fixed position, varies with liquid depth. Motion of float is transmitted through torque tube to flapper (Fisher Governor, others). Pneumatic balance described in Section 25(b) can be used to operate control valve and indicate buoyant force in terms of level. Range: Height of displacer. Accuracy: High. Remarks: System is now used extensively where high-precision control is needed (i.e., perhaps in 85% of all control installations).

(b) Hydrostatic Pressure Methods

FIG. 77—DIRECT HYDROSTATIC TYPE with gage on tank. Knowing density of liquid, its height above a pressure gage on tank can be inferred directly from gage reading. Range: Limited only by tank height. Accuracy: 1%. Remarks: Limited to tanks not under pressure.

FIG. 78—AIR BUBBLER. Similar to bell and diaphragm, except that air flow is maintained through dip pipe instead of being trapped in the unit itself. Range: Limited only by tank height. Accuracy: About 1%. Remarks: Widely used with practically all kinds of liquids, including corrosive ones. Requires about 3 cu. ft./hr. of air.

FIG. 79—DIFFERENTIAL-PRESSURE BUBBLER. Used instead of the unit shown in Fig. 78, if the tank is under pressure. Back pressure in dip pipe is tubed to one side of the manometer, tank pressure to the other. Range: Limited only by tank height. Accuracy: About 1%. Remarks: Uses are similar to those mentioned for the unit in Fig. 78.

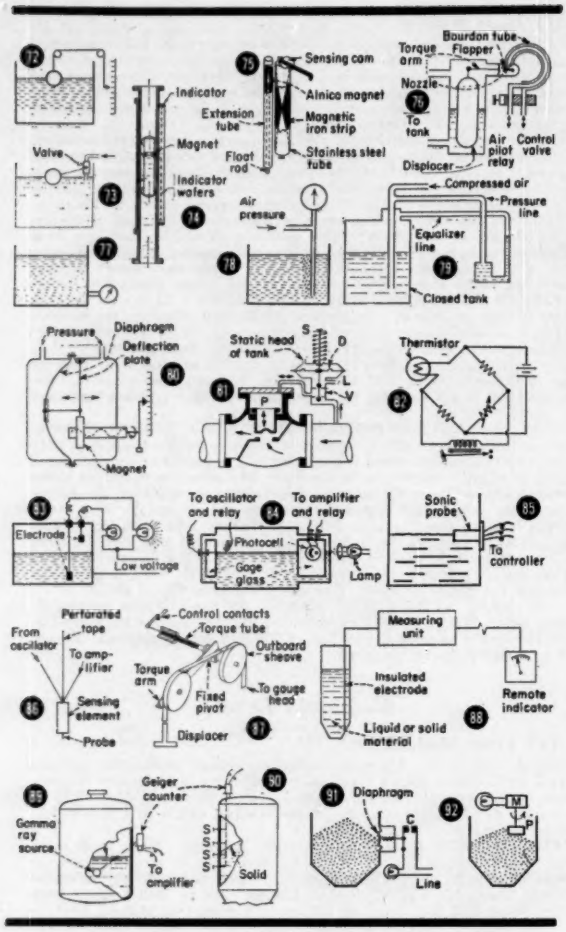


FIG. 80—SLACK-DIAPHRAGM TYPE (Yarnall-Waring Co.). Differential-pressure manometer has magnetic transmission converting motion of diaphragm to rotary motion of indicator. Range: 0-3,000 psi. static; 6-360 in. water-gage differential. Accuracy: ±3% or better. Remarks: Used for level measurement in boilers, heaters, and process vessels under pressure. Also for other differential-pressure purposes, such as flow measurement.

FIG. 81—ALTITUDE VALVES (Golden-Anderson). Main valve (at water-pressure pilot) is controlled to admit water to elevated tank. Head in tank is balanced by spring *S* on diaphragm *D*. An increase in head lowers pilot valve *V*, closes leak *L*, applies main line pressure to top of piston *P*. Since area of *P* exposed above is larger than below, main valve closes. If head decreases, *L* opens and *V* closes; thus, *P* opens. Range: 2- to 36-in. pipe size. Accuracy: Unit controls within 3-12 in. Remarks: Used to hold constant heads in elevated tanks.

(c) Other Methods

WEIGHING VESSEL. In a scale-balanced vessel, height of liquid is proportional to weight. One variation of this general type is a device that weighs or spring-balances a small auxiliary vessel that has been attached top and bottom to the main vessel with flexible leads. Range: Limited by practical considerations. Accuracy: High. Remarks: Where practical, this is the most accurate method readily available. Auxiliary-tank method has been used on pressure vessels.

FIG. 82—TEMPERATURE-CHANGE DETECTOR (Gulton Industries). Self-heated thermistor in a bridge-circuit changes its resistance when surrounding medium changes from air to liquid, thus unbalancing the bridge and operating the relay that controls the filling system. Range: Most liquids. Accuracy: ±0.1 in., in any depth. Remarks: Simple system either for level-detecting or for the control of filling or emptying.

FIG. 83—LIQUID-CONDUCTION TYPE. Probes are installed at desired high and low levels. By conduction of electricity, probe circuitry operates valves, pumps or signals. Can be used with electronic amplification for low-conductivity liquids (e.g., units of B/W Controller Corp., others). Range: Liquids must have some conduction. Accuracy: High. Remarks: Used for high-low signalling control. Cannot indicate intermediate levels.

FIG. 84—GAGE-GLASS AUTOMATIC DETECTOR. Level in gage glass at control point can be detected by condenser plates in an oscillator circuit, or by reduction of light received by a photo cell. Range: Limited only by gage glass. Accuracy: High. Remarks: Suitable either for control or for signalling in tanks equipped with a gage glass.

FIG. 85—ULTRASONIC PROBE (Powerton Ultrasonics). Operates magnetostrictively, such that surface of probe vibrates at 40 kc. when exposed to air. When liquid contacts the probe surface, however, oscillations in controller cease; and controller actuates alarm or other relay. Remarks: Operates independently of density, dielectric constant, temperature, pressure or conductivity variations. Not adversely affected by froth, foam, or liquid films. Unaffected by pressures to 2,000 psi. or temperatures between −450 to 500 F.

CAPACITANCE PROBE (Robertshaw, A.&I. Div.; CompuDyne Corp.). Glass-covered probe for high or high-and-low levels will detect level or interface level by capacitance changes, using oscillator electronic circuit. Conducting liquid is unnecessary. This type is not for continuous levels (see Fig. 88). Range: Unlimited. Accuracy: To 1/32-in. Remarks: Can distinguish between liquid and foam. Glass coating makes the probe corrosionproof. Coatings other than glass are available (polyethylene, Teflon, ceramic). Available for both electric and pneumatic control.

FIG. 86—ELECTRONIC LEVEL GAGE (Gilbert & Barker Mfg. Co.). Level-sensing device is a small radio antenna in an open-end cylinder. Antenna radiates minute radio-frequency signals that are affected by submersion. The deeper the submersion, the weaker the signal. Return signal, sent up the same cable, retains same strength. Electronic unit compares up and down signals, moves sensing unit (as a surface follower) by means of a servo motor to hold the signal ratio constant. Tape-supporting sensor then reports the exact level by measuring the hoisting-drum position, telemetering the value to remote indicator. Range: Unlimited. Accuracy: ±1/16-in. Remarks: No possibility of float sticking. Can telemeter long distances. Temperature readings are telemetered at the same time.

FIG. 87—LIQUID-LEVEL GAGE (Vapor Recovery Systems) has force-measuring device consisting of a torque tube, an arm and its contacts, and a solid displacer suitable for the environment. Weight of displaced liquid produces a proportional change in force on the torque tube, causing motor to move tape up or down in response to liquid level. Balance is restored when displacer is accurately positioned in relation to liquid level. Compensation for weight of tape is provided by tape storage-sheave in indicating unit. Range: To 60 ft. depth. Accuracy: 1/16-in.

FIG. 88—CONTINUOUS CAPACITANCE GAGE (Robertshaw, A.&I. Div., others). Insulated metal electrode is one side of a capacitor; other side is the tank wall. Variations in dielectric character of the material between electrode and wall are measured on a capacitance bridge as the level of the air-material interface moves. Range: Up to 200 ft. depth. Accuracy: ±2%. Remarks: Can also be used to monitor the depth of solids. Electrode can be protected against corrosive materials. Indicators may be at remote panel.

FIG. 89—GAMMA-RAY ABSORPTION. Gamma-ray source in vessel gives off radiations that are detected by a Geiger counter outside the tank. Geiger output decreases as level rises, and can be calibrated in terms of level. To cover a wide range, several gamma sources are used at different levels. Geiger output is amplified and converted to d.c., proportional to pulse rate. Atomic battery (Ohmart, Section 4) may be used for detection instead of a Geiger counter. Remarks: Can be used where most other level methods might be banned for safety reasons. No opening is needed through vessel. Can be used for control.

7—Solids Level

FIG. 90—GAMMA-RAY GAGE. One or more sources of gamma radiation within a solids-containing vessel give off rays that are detected by a Geiger counter located outside the vessel. Absorption depends both on density of medium and on length of rays' path through solids; hence, radiation received by the counter is inversely proportional to level (or density) of solids. Atomic battery (see Ohmart, Section 4) may be used for detection. Range: Solids level of about 2 ft. per source, depending on density. Remarks: Used in solids bins, fluid and other cat crackers. Requires no opening or connection through vessel wall. If height is known, then density of fluidized beds can be determined.

FIG. 91—FLEXIBLE-DIAPHRAGM TYPE (Bindicator Co.). Flexible diaphragm in bin wall moves if contacted by solids, thus operating a switch. When level falls, a spring returns the diaphragm and switch to former position. Range: Unlimited. Remarks: One unit can be used to detect either high or low level of solids. Two units detect both high and low, and operate signals or conveyors. Intermediate levels are detected similarly.

FIG. 92—ROTATING-PADDLE TYPE (Fuller Co., others). Paddle *P* at desired top level is rotated by a motor *M*, mounted so that increased torque operates a switch when solids reach paddle. Range: Unlimited. Remarks: Can be used only for top-level detection, but operates signal or shuts off conveyor.

PENDANT-CONE TYPE (Stephens-Adamson Mfg. Co.). Cone with apex upward is suspended from housed switch so that movement of solids in any direction from vertical makes contact. Range: Unlimited. Remarks: Can be used only for top-level detection, but operates signal or shuts off conveyor.

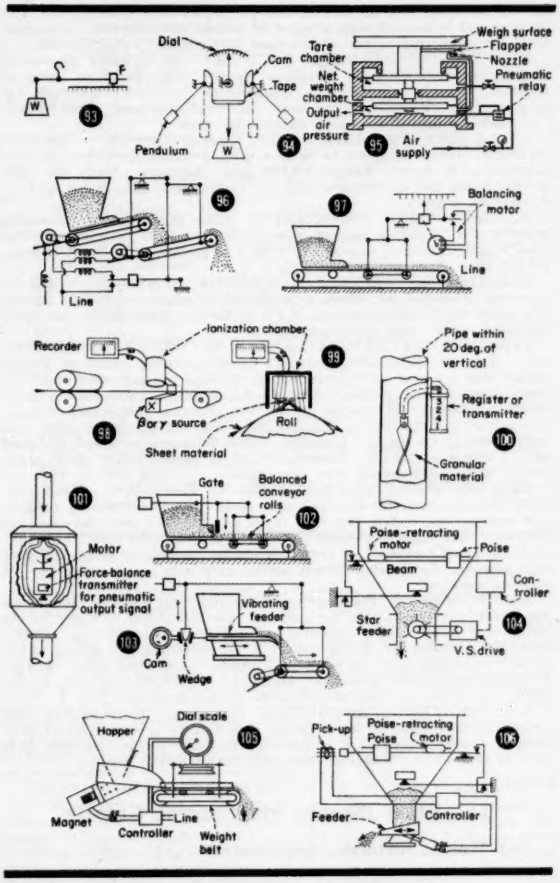
BALANCE-PADDLE TYPE (Conoflow Corp.). Paddle on horizontal arm extending into vessel through diaphragm seal is balanced by pneumatic-balance transmitter. Contact with solids unbalances arm, which transmits signal to indicator or controller. Range: Unlimited. Accuracy: High. Remarks: Designed to measure level of hot catalyst at temperatures to 1,000-1,100 F. Rapid response.

SLACK DETECTOR (Dracco Corp.). Small weight on a cable is lowered periodically into bin by a cycle-controlled winch. When it strikes solids, a slack detector stops and reverses winch, leaving indicator at corresponding position. Cycle then repeats so that indicated level is cor-

rected each cycle. Range: Any practical height. Accuracy: High. Remarks: Intended primarily for continuous indication and recording of level in bins, but can also be used for control.

WEIGHING VESSEL. If vessel diameter is known, then the most accurate method of determining solids level—where practical—is to weigh vessel and contents. Range: Limited by practical considerations. Accuracy: High. Remarks: Uncommon method, limited by expense of weighing large bins. Strain-gage weighing may increase use.

FEED CONTROL for grinding mill based on grinding noise level (Hardinge Co.). Microphone near a ball, rod or tube mill indicates sound level at which material level in mill is optimum for maximum grinding action. Microphone output is amplified, used to control feeder. Range: Limited only by available mill sizes. Accuracy: High. Remarks: Work being accomplished by mill is directly related to amount of sound produced. Method prevents over- or underloading without operator attention.



8—Weight and Weight Rate of Flow

(a) Fixed-Load Weighing

FIG. 93—UNEVENLY BALANCED SCALE. Simplest form of the steelyard, shown in Fig. 93, which illustrates principle of most weight-balanced industrial scales. Unknown weight on a short moment-arm is balanced by movable known poise (or known weights plus poise) on a long moment-arm. Industrial scales (e.g., see Fig. 96) introduce additional levers between unknown weight and beam in order to increase ratio of unknown to poise. Range: To 400,000 lb., or more. Accuracy: About 0.1% of actual weight is possible. Remarks: Most widely used weighing method for industrial use. Includes manual and automatic types. Indications on dial available. Some types print weight automatically.

FIG. 94—PENDULUM-BALANCED SCALE. One or more pendulums can balance increasing loads as they move from vertical (zero) to horizontal (maximum). Because the balanced load varies with the sine of the displacement angle, cams are used to give linear scale graduation. Cam may either be on the pendulum or on the pointer. Metal tape transmits motion. Range: Same as beam scales, since lever reduction can be used ahead of pendulum mechanism. Accuracy: Same as beam scales. Remarks: Commonly used, especially where dial indication of weight is desired. Available in recording and printing types, with optional photoelectric cutoff. Toledo has developed remote digital recording for the unit.

SPRING-BALANCED SCALE. Within limits, spring deflection is directly proportional to load. Hence, deflection can be used as a measure of weight supported. Range: Generally used for moderate weights. Accuracy: Can be as high as 0.05%. Remarks: Commonly used for small commercial scales, but is also used to balance the beam in automatic industrial scales.

HYDRAULIC- or SPRING-BALANCED SCALES. The force produced by a load is detected by a liquid-filled capsular element and transmitted to a spring-loaded, pressure-sensitive element. Range: Used mainly for moderate to large loads. Accuracy: High. Remarks: Used in crane-hook scales and other industrial applications.

FIG. 95—PNEUMATIC WEIGHT TRANSMITTER (Weighing & Controls, Inc.) operates on force-balance principle. When weight is applied to surface, flapper regulates flow of air through nozzle. On increased weight, flapper reduces nozzle opening; hence, air pressure in the chamber increases. When total force on diaphragm equals weight on platform, equilibrium is established. Since chamber pressure is a measure of weight, value of the former is transmitted to operate an indicating, recording or controlling device. Range: 0 to 8,200 lbs. with output signal from 5 to 40 psig. Accuracy: ±0.25%. Remarks: Range of a given unit is determined both by air pressure supplied and by effective diaphragm area.

TENSION-BALANCED LOAD CELL or STRAIN GAGE (Baldwin-Lima-Hamilton Corp.). See Section 3, and Fig. 35 of Section 2(c). Strain gages, bonded to a calibrated tension element, measure load in terms of the lengthening of element. Resistance change in strain gage is measured by a bridge circuit. Unbonded strain gages may be used for smaller loads. Range: Up to 50,000 lb. per load cell. Accuracy: ¼% full scale. Remarks: Used for both stationary and moving loads. Easily weighs tanks, bins and hoppers. Made also in automatic printing type (by Streeter-Amet Co.).

(b) Moving-Load Weighing

FIG. 96—SEMICONTINUOUS FEED-BELT WEIGHER (Richardson Scale Co.). Scale-balanced weigh belt controls the operation of a feed belt. Scale belt runs continuously, but certain sections of its total length are fed intermittently with loads. Definite increments of load can thus be weighed. Increments come close together, approximating continuous flow. Accuracy: High. Remarks: Used to record the receipt and withdrawal of bulk materials; also, for batching of solids.

SCALE-MOUNTED FEED TANK (for liquids). Feed tank on scale is filled to set point, after which feed valve is closed. Tank discharges automatically. Weight is registered, and cycle repeats. Variation of this type, used for accurate weight rate of feed, allows liquid to discharge only as fast as weight-setting of scale decreases through the action of motor-driven beam poise (Proportioneers Inc.). Range: Limited only by practical weight-tank size. Accuracy: 0.1%. Remarks: Used where accuracy of other methods (such as volumetric or head-type flow metering, or pump displacement) is insufficient.

FIG. 97—CONTINUOUS CONVEYOR SCALE. Many variations stem from the basic idea of totalizing continuous loads on a scale-balanced section of a belt conveyor. Various forms of automatic weighers are used, including spring-balanced beams, strain-gage load cells and motor-driven-poise self-balancing scales. Totalizer integrates instantaneous loads with belt speed to correct for possible belt-speed variations. Range: Limited only by conveyor sizes available. Accuracy: ½ to 2% depending on % of rated load. Remarks: Commonly used on bulk materials where continuous record is needed for inventory purposes. Such scales give quick response to load variations. Some units subtract the weight of material sticking to return belt.

FIG. 98—RADIOACTIVE TRANSMISSION GAGE, ABSORPTION TYPE (see also Section 9 and Fig. 99). (Industrial Nucleonics Corp., others). Beta or gamma radiation from a radioactive source passes through moving web of material to an ionization chamber. Attenuation of signal is a measure of the weight of material passing. Recorded as either weight or thickness. Range: Usual thickness of sheet materials. Accuracy: 1-2% or better. Remarks: Used for continuous measurement of weight per unit area (or thickness) of moving webs of sheet materials such as paper, rubber, plastics, coated fabrics, metals. Unaffected by water, surface finish, etc.

FIG. 99—RADIOACTIVE TRANSMISSION GAGE, BACK-SCATTERING TYPE (see also Section 9 and Fig. 98). (General Electric, others). Variation of absorption type, where (a) source and ion chamber are on the same side of material measured, and (b) radiation is reflected from the backing plate being measured. Unit measures either passing weight or thickness, depending on calibration. Range: Usual thicknesses of sheet materials. Accuracy: 1-2% or better. Remarks: Used for continuous measurement of weight, or thickness on moving webs of sheet materials such as paper, rubber, plastics, coated fabrics, metals. Also measures thickness of surface coatings on metals (e.g., tin or in combination, tin and zinc) and plastics.

FIG. 100—VOLUMETRIC SOLIDS METER (Bailey Meter Co.). Spiral vane, suspended in a duct containing moving solid material, rotates without slip in proportion to motion. A connected register records the revolutions in terms of integrated passing volume or weight. Can transmit to remote integrator. Range: For spouts 10 in dia. or larger. Accuracy: ±3% of actual material weight. Remarks: Device is used on spouts not over 20° from vertical. Being volumetric, device must be calibrated on material handled to permit conversion to weight flow.

(c) Weigh Feeders

FIG. 101—WEIGHT RATE METER (Wallace & Tiernan). Dry free-flowing material falls on rotating impeller driven by synchronous motor. Motor is mounted on flexure pivots, and is free to move about axis of shaft. A torque is created on motor frame when particles of material are accelerated to velocity of rotating impeller. Torque is proportional to weight rate of flow, and is converted to air signal by means of a pneumatic force-balance transmitter. Range: 40-200 lb./min. Accuracy: ±0.2%. Remarks: Fast response to flow changes. Output

signal may be used to control feeder in a closed loop, or to control the operation of other pneumatic devices for ratio control.

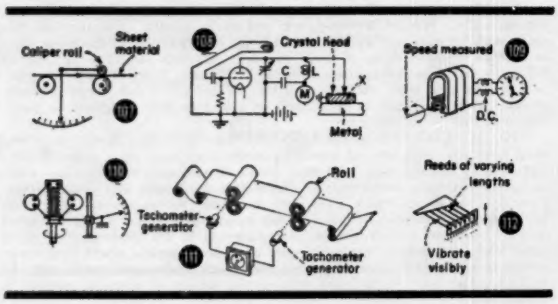
FIG. 102—SCALE-BALANCED BELT FEEDER (Schaffer Poidometer). Scale-balanced belt controls the setting of feed hopper gate to maintain constant weight on belt. Range: Moderate. Remarks: Used for feeding solids at a constant rate to processes.

FIG. 103 — BALANCED WEIGH BELT, MECHANICAL FEEDER (B-I-F Industries). Short feed belt, carried on a scale, is fed by a mechanically vibrated tray (smaller in later models than shown). Feed rate is controlled by the tray's oscillation, which in turn is governed by raising or lowering the scale beam's resilient wedge. Range: Feed is adjustable over a 100-to-1 range; maximum is 10,000 lb./hr. Accuracy: 1% of feed rate. Remarks: Used on all types of free-flowing solids, for both feeding and proportioning. Variable-speed star feeder may be substituted for vibrator.

FIG. 104—LOSS-IN-WEIGHT STAR FEEDER (B-I-F Industries). Scale hopper is discharged by a variable-speed star feeder. Scale-beam counterpoise is retracted continuously by a constant-speed motor. Pneumatic controller holds the beam in balance by matching discharge rate with whatever feed rate has been set by the retracting poise. Range: 100-to-1 feed range; maximum is 40,000 lb./hr. Accuracy: ±½% of feed rate. Remarks: Handles dry materials in chemical, fertilizer, plastic and other industries. Feed may be granular, lumpy, stringy, etc. Poise-retraction speed is adjustable.

FIG. 105 — BALANCED BELT, ELECTRIC VIBRATING FEEDER (Syntron Co., others). Weight of material on a short feed belt is controlled continuously by automatically adjusting the vibration amplitude of an electrically vibrated trough feeder. Range: Wide. Remarks: Suitable for free-flowing solids. Adjustable over wide range.

FIG. 106—LOSS-IN-WEIGHT VIBRATING FEEDER (Syntron Co.). Scale hopper is discharged by an electric vibrating feeder. Scale-beam counterpoise is retracted continuously by a constant-speed motor. Electronic pickup and control system adjusts the feeder's rate to match whatever feed rate has been set by the retracting poise. Range: 3-cu. ft. hopper. Accuracy: Less than 1% error. Remarks: Handles dry chemicals and similar materials. Poise-retracting speed is fully adjustable.



9—Thickness and Displacement

FIG. 107—CALIPER ROLL. A roller rides on top of moving sheet material, while a fixed-reference roller is positioned beneath the sheet to measure the material's thickness by its distance from reference. Measurements are multiplied in various ways, such as mechanically or by a strain gage. Range: Usual thickness of sheet materials. Accuracy: Variable, depending on construction. Remarks: Suitable for moving webs of sheet materials where physical contact will not be harmful.

PNEUMATIC JET. Moving sheet material, passing over a reference roll, can be gaged by back-pressure in a jet directed at, and close to, the surface. Unit can be hooked into a pneumatic force-balance system for amplification and transmission of indication. Jet can also be used for edge-tracking (Askania). Range: Usual thicknesses of sheet materials. Accuracy: High. Remarks: Variations of this system have the advantage that physical contact with moving web is not required.

FIG. 108—ULTRASONIC-RESONANCE GAGE (Branson Instruments). A crystal head contacts the test material, sending an ultrasonic wave through it. Wave reflects back to head. When round-trip time equals vibration frequency, resonance is attained, causing an increase in circuit power. Frequency is set by adjusting the values of C and L. Point of maximum energy absorption can be determined from microammeter M. Range: 1/16- to 12-in. metal thickness. Accuracy: 3% or better. Remarks: Calibrated from known thickness of material to be measured. Can determine thickness of pipes, vessels, etc., where other surface is not available. Used in checking for corrosion.

BETA AND GAMMA RAY ABSORPTION AND BACK-SCATTERING. See Section 8(b), Figs. 98 and 99. Same principle is used for measuring thickness as for weight. Weight is actually measured here, although unit can be calibrated to report thickness if density is constant. Similar principle is used in detecting corrosion-thinning of pipe and tank walls, by measuring thickness from one side. Range: Usual thicknesses of sheet materials. Remarks: Used for continuous thickness measurements on web materials such as paper, rubber, plastics, coated fabrics, metals. Unaffected by water, finishes, etc.

X-RAY BACK-SCATTERING (Philips Electronics, Inc.). X-ray beam is set at 70° from surface of moving tin-plate sheet, producing a secondary radiation from steel backing. Secondary rays are back-scattered to Geiger tube; their intensity is a function of tin plate's thickness. Duplicate units on both sides of the plate are able to gage both surfaces. Two-beam type (Applied Research Laboratories) compares reflected K-radiation from tin with scattered radiation from parts of spectrum that are independent of tin thickness, records ratio of two types as weight. Range: Usual tin-plate thicknesses. Accuracy: High. Remarks: Used specifically for tin plate.

10—Velocity (Linear and Angular)

AIR-SPEED INDICATORS include such devices as cup, vane and hot-wire anemometers; and pitot tube. Range: Various. Accuracy: Various. Remarks: Used in meteorology, flight, air-conditioning and ventilation.

CONVERSION OF LINEAR TO ANGULAR VELOCITY. Speed of moving surfaces, such as moving web or surface of a drum or roll, can be measured by contact with a wheel of known circumference. Remarks: Used for measuring output of processes that produce web materials.

FIG. 109—D.C.-MAGNETO TACHOMETER. Small permanent magnet generator produces a voltage directly proportional to speed of rotation. Measured by voltmeter. Range: 1 to 5,000 rpm. Accuracy: Up to about 1%. Remarks: Commonest industrial rotational speed device. Can easily be geared for speeds beyond its range.

A.C.-GENERATOR TACHOMETER (General Electric). Single-phase alternator, driven at speed to be measured, produces frequency directly proportional to speed. Range: 0-4,000 rpm. Accuracy: About 4%. Remarks: Needs less maintenance than d.c. tachometers, since it has no commutator or brushes.

MAGNETIC-DRAG TACHOMETER is the type used in automobile speedometers. Rotating magnet induces eddy currents in a surrounding aluminum cup, tending to drag cup with it in proportion to speed. Range: 0-2,000 rpm. Accuracy: Up to 10%.

FIG. 110—CENTRIFUGAL GOVERNOR. Flyballs, restrained by a spring, compress the spring proportional to square of speed. Range: Top about 40,000 rpm. Accuracy: 1% or better. Used chiefly for speed regulation rather than measurement.

FIG. 111—DIFFERENTIAL SPEED RECORDER (General Electric). Two d.c. tachometer generators convert rotating speeds to voltage signals that are sent to recorder. These voltages are reduced to millivolt level by high-resistance voltage-divider input circuits. If voltages are equal, speeds are equal. If process speeds are changed, tachometer voltages change; and servo motor in the recorder will deflect pointer on slide wire until voltages are equal. Indicator shows difference in speed or speed ratio. Accuracy: ±0.1%. Remarks: Used in paper-machine draw, strip-rolling mill, and manmade fiber operations.

FIG. 112—VIBRATING REED (Jas. G. Biddle Co.). Meter contains a set of consecutively tuned steel reeds. When a vibrating machine part contacts the meter, any reed tuned to resonance with the vibration frequency will respond visually. Range: 600 to 100,000 rpm. Accuracy: 0.5% of actual frequency or better. Remarks: Capable of measuring very high vibration frequencies. Needs contact only with a nonmoving part of rotating machine.

STROBOSCOPES. For measurement of rotational speed or other cyclic movement, stroboscopes can be used to "stop the motion." Speed of the stroboscope itself is then measured without need to contact the rotating part. Stroboscopes are of various types, all permitting the moving object to be viewed once per cycle, as with shutter or flashing light. Range: Unlimited, by use of harmonics. Accuracy: Synchronization perfect. Remarks: Main use in experimental work, trouble-shooting.

TACHOMETER TRANSMITTER (Foxboro). Magnetic-drag disk torque is transmitted by a pneumatic force-balance system. Output pressure is directly proportional to speed of rotation. Range: Various, from zero to 12,000 rpm. Remarks: Developed for industrial systems.

11—Fluid Density and Specific Gravity

(a) Weight methods, Hydrometer

HAND HYDROMETER. Weighted float, with small-diameter stem at top, sinks in liquid to depth proportional to specific gravity. Scale is read at liquid level. Range: Adaptable to any specific gravity. Accuracy: Third or fourth decimal place. Remarks: Widely used where automatic operation is not needed.

(b) Weight methods, Fixed Volume

FIG. 113—BALANCED-FLOW VESSEL (Halliburton) is a fixed-volume vessel through which liquid flows continuously. Liquid is weighed automatically by a scale or a force-balance transmitter. Range: Any specific gravity of liquids. Accuracy: ±1%. Remarks: Generally applicable to automatic density control.

FIG. 114—GAS SPECIFIFIC-GRAVITY BALANCE (Alpha-Lux). Weight of tall gas column is measured against air by floating bottom of gas vessel, which is scale-balanced. Range: Any density of gases. Accuracy: High. Remarks: Similar to, but more convenient than, two-pipe system described above. Suitable for any gas. Can be designed to record values.

FIG. 115—BUOYANCY GAS BALANCE (Edwards). Displacer on balance beam in vessel is balanced for air; manometer reading is noted at exact balance pressure. Air then displaced by gas, and pressure adjusted until balance is once again attained. Ratio of pressures is density relative to air. Range: Any density of gas. Accuracy: Fourth decimal place. Remarks: Used mainly for high-precision laboratory measurements. Cannot be adapted to continuous measurement.

INDUSTRIAL SPECIFIC-GRAVITY DISPLACER. Similar to displacer for level measurement [See Section 6(a)], except that float is sub-

merged and externally counterbalanced. **Range:** Any liquid density. **Accuracy:** Second or third decimal place. **Remarks:** A widely used method for industrial recording and control of liquid density.

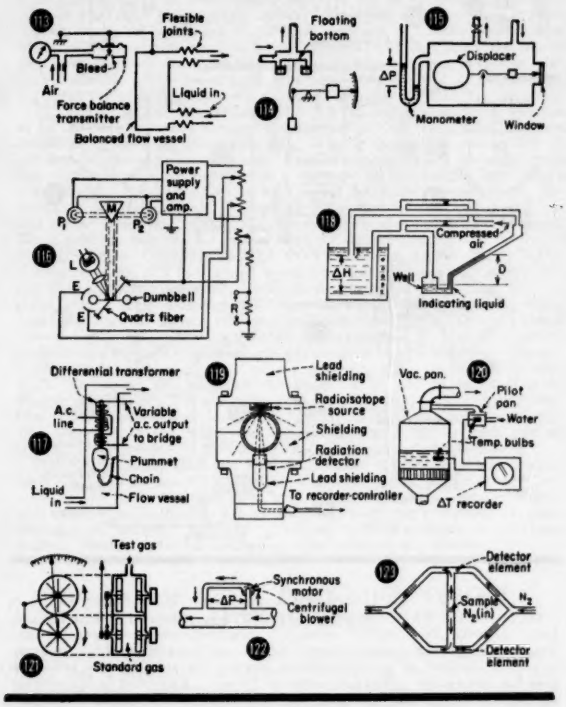


FIG. 116—GAS-DENSITY BALANCE (Beckman Instruments, Inc.). A null-balance instrument. Gas density is measured by buoyancy of one ball of a dumbbell as compared with the other. Reference ball is punctured, therefore not subject to buoyancy effects. Rotation of rhodium-coated dumbbell about horizontal quartz fiber produces electrostatic force between electrodes and the suspension. Balancing potential is obtained and measured by the amount of light received by phototubes P_1 and P_2. Rebalance potential nulls the balance, is recorded as gravity relative to air. Range: 0-2,000 relative to air. Accuracy: ½%. Remarks: Continuous measurement of a process stream. Compensated for barometric changes. Calibrated manually on known reference gas, usually air. Single range has total span of 0.100 units; multirange is 1,000 units relative to air.

FIG. 117—CHAIN-BALANCED-FLOAT DENSITY RECORDER (Precision Thermometer & Instrument Co.). The bob in a continuous flow vessel is weighted to carry half the weight of a light chain, when submerged in medium-density liquid at midpoint in its range. Chain is attached to bottom of float and to vessel wall at half-height. Any increase in density causes float to rise, supporting more chain; any decrease causes it to sink, supporting less chain. Float position is transmitted by differential transformer. Range: Liquid gravity range, 0.6-3.5 specific gravity units. Accuracy: High. Remarks: Can be used for recording, control, or both. Resists most corrosive conditions; suitable for practically any liquid. Note that this is a method of actually weighing a fixed volume of liquid. Can be corrected for temperature variations.

(c) Other Methods

FIG. 118—DIFFERENTIAL AIR BUBBLER (Petrometer Corp.). Air at regulated pressure and quantity is bubbled through two dip tubes of different lengths submerged in liquid. Differential pressure is a measure of the weight of liquid column between dip-tube ends, and hence of the liquid's specific gravity. Head D of indicating liquid is directly proportional to specific gravity of liquid in tank. **Range:** Any liquid density. **Accuracy:** 0.001 specific gravity units. **Remarks:** Suitable for practically all liquids, except those that will crystallize in the measuring pipes. Can be used on suspensions, and on stationary or flowing liquids. Can use liquid instead of air in place of inclined manometer. Diaphragm-type manometer can be used.

FIG. 119—GAMMA-RAY DENSITY GAGE (Industrial Nucleonics, Ohmart). Gamma radiation from cesium-137 source passes through liquid. Amount of energy reaching detector varies inversely with density of process stream. **Accuracy:** ±2%. **Remarks:** Unit takes continuous density measurements of solutions, liquids, slurries, divided solids.

FIG. 120—BOILING-POINT ELEVATION. Compares temperature of boiling solution with that of water boiling at same pressure. For particular solution, boiling-point elevation can be calibrated in terms of density at standard temperature. **Range:** One dissolved component, or mixtures of fixed composition. **Accuracy:** High. **Remarks:** Method used in evaporators for determining end-point of evaporation. Unit commonly uses resistance thermometers to record difference in the two temperatures.

FIG. 121—VISCOUS-DRAG GAS-DENSITY METER, Ranarex type (Permutit Co.). Driven impellers in standard and test gas chambers produce opposite rotation in gas column. Nonrotating impellers, coupled together by linkage, measure relative drag. Balance point depends on relative density. **Range:** Usual industrial gases. **Accuracy:** About 0.01 specific gravity units. **Remarks:** Often used for determining compensation of binary gas mixtures—which makes the operation an analysis rather than a straight density-measurement. Calibrated on gases to be measured.

FIG. 122—GAS DENSITOMETER (Rotron). A constant-speed centrifugal blower in the bypass line produces a pressure rise that is proportional to gas density. Differential-pressure transducer sends signal to recorder. **Accuracy:** ±0.10%. **Remarks:** Does not require correction for gas compressibility. Used with velocity flowmeter (Fig. 66) as gas mass-flow device.

FIG. 123—GAS-DENSITY DETECTOR (Gow-Mac Instrument Co.). Pneumatic wheatstone bridge, mounted in vertical plane, contains two thermistor detectors. Carrier gas may be nitrogen, argon or other heavy gas to act as reference. When flow is balanced, detectors are equally cooled; and bridge is balanced. Sample gas enters and is split into two streams. If density is different from that of reference gas, unbalance of electrical bridge results. Response (in form of chromatographic peaks) is measured on recording potentiometers. **Remarks:** Sample does not come in contact with detector elements.

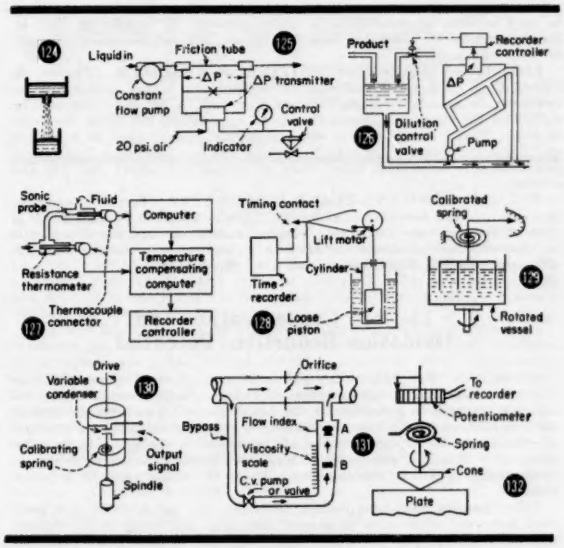


FIG. 124—TIMED DISCHARGE THROUGH NOZZLE. This is the method used by viscometers such as the Saybolt. Vessel with short capillary tube has discharge that is timed to release at desired temperature. **Range:** Low to moderately high. **Accuracy:** High. **Remarks:** Commonly used for expressing viscosities of oils.

FIG. 125—PRESSURE DROP THROUGH FRICTION TUBE (Hallikainen, Precision Scientific). Liquid is pumped at a constant rate through friction tube in viscous flow. Pressure drop across ends of tube is measured in terms of absolute viscosity by pneumatic force-balance-type of differential-pressure transmitter. Constant-temperature bath contains sensing elements. **Range:** Up to 3,000 centipoise. **Accuracy:** 0.2 cp. in span of 50 cp. **Remarks:** Unit takes a wide range of industrial liquids. Can be used for remote recording and control. Extremely simple and foolproof. Requires no attention.

TIMED FALL-OF-BALL OR RISE-OF-BUBBLE. Time for fall of metal ball, or rise of bubble, through liquid confined in tube is proportional to absolute viscosity (since, in either case, liquid flows in viscous flow through a definite restriction). **Range:** Used primarily for high viscosities. **Accuracy:** High. **Remarks:** Both are laboratory methods commonly used in measuring oil viscosity. Ball method can be timed by field coils at start and finish with great accuracy.

FIG. 126—CONTINUOUS CONSISTENCY METER (Fischer & Porter Co.). Gear pump diverts a portion of product stream through a flow bridge, where a pressure differential between two reference points is established. Differential pressure is a direct measure of the consistency of the material. **Remarks:** Measures, records and controls the consistency of fibrous or pulpy slurries.

12—Viscosity and Consistency

FIG. 127—ULTRA-VISCOSON CONTINUOUS VISCOMETER (Bendix Corp.). Ultrasonic waves are applied to a thin magnetostrictive alloy-steel blade. Rate at which oscillations of the blade are damped is a measure of viscosity of the sample. Relation between damping and viscosity is solved continuously by a computer. Range: 0-50,000 centipoise-grams/cc., in four steps. Remarks: Ultra-Viscoson can be used for Newtonian or non-Newtonian liquids and high polymers. Probe can be immersed in any process vessel, as well as in laboratory equipment.

FIG. 128—PISTON VISCOMETER (Norcross Corp.). Piston is raised in a timed sequence, and falls by gravity through the liquid. Clearance between piston and cylinder is the measuring orifice. Time of fall is recorded as a measure of viscosity. Range: 0.1 to 10^6 centipoises. Remarks: Covers the same range of materials as does the unit shown in Fig. 127.

FIG. 129—DRAG TORQUE ON STATIONARY ELEMENT IN ROTATED CUP. Some types use a cylinder; others, a paddle as shown (Brabender). Liquid cup rotates at constant speed. Stationary element is restrained by calibrated spring that, by angular displacement, measures torque in terms of viscosity. Range: Wide, for both Newtonian and non-Newtonian fluids. Accuracy: High. Remarks: Unit is primarily a laboratory instrument but may be equipped to record. Bowl is often surrounded by thermostatic housing for close temperature control.

FIG. 130—ROTATING-TORQUE TYPE (Brookfield Engineering Laboratories, Inc.). A synchronous motor drives a vertical spindle with disk, paddle or cylinder submerged in test liquid. Drive is through calibrated spring. The object is to determine the torque required to rotate a torque element in a liquid. Angular lag of element's spindle behind motor is proportional to viscosity and is measured in various ways. Controller detects angle of displacement by periodic electric contact. Recorders adapted to this device by several instrument makers measure angle three ways: capacity change, resistance change, timed impulse. Range: 0-500 poises, with minimum span of 0-1 cp. Accuracy: 1 to 2%. Remarks: Can be used in open or closed vessels, under pressure or vacuum, at high or low temperatures. Used for both Newtonian and non-Newtonian liquids or suspensions.

FIG. 131—VISCOSITY-SENSITIVE ROTAMETER (Fischer & Porter Co.). Rotameter bobs can be designed for either sensistivity or immunity to viscosity. With constant flow rate, a sensitive bob can be calibrated for viscosity. One method is to use immune bob to set flow rate at index mark. Range: Up to 400 centistokes; special type, to 1 million cp. Remarks: Suitable for both Newtonian and non-Newtonian liquids and suspensions in continuous flow. Used for visual and remote readings and control.

FIG. 132—CONE-AND-PLATE VISCOMETER (Ferranti) measures viscosity of non-Newtonian systems. Sample fluid (0.5 milliliters) is sheared between cone and plate. Viscous traction on cone exerts a torque on electromechanical dynamometer, which gives reading on measuring instrument. Range: Shear rates from 2 to 20,000 $(sec.)^{-1}$.

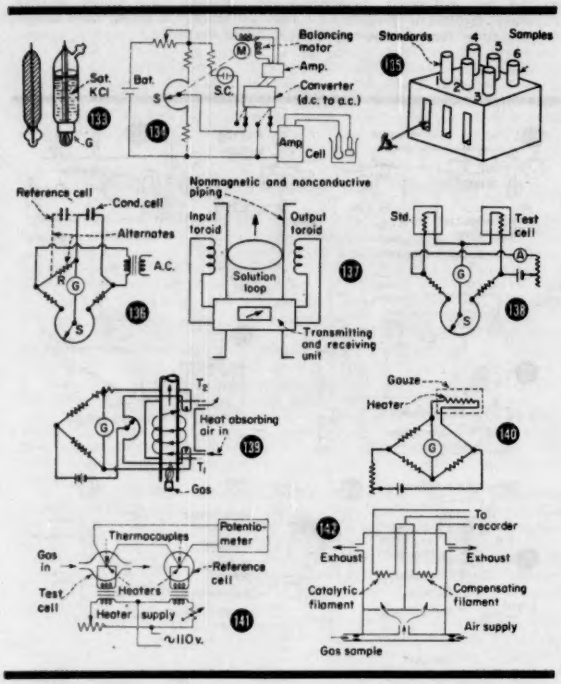
13—pH Concentration and Oxidation-Reduction Potential

GENERAL (See **FIG. 133.**) pH is a measure of effective acidity or alkalinity, indicated as concentration of hydrogen ions present. Numerical measure is negative logarithm of the concentration. Fundamental method, used in calibration and laboratory work, is hydrogen electrode vs. standard calomel electrode. Both electrodes are immersed in the liquid to be measured, at a standard temperature; electrodes produce a potential that is proportional to H-ion concentration. Result is measured with a potentiometer.

Other possible electrodes include antimony and quinhydrone, not much used now; and glass, now in general use. Fig. 133 shows glass electrode and calomel reference-electrode. Glass electrode is thin glass bulb with silver electrode immersed in silver salt solution, now available in types of pH-0 to pH-14. Calomel electrode produces a fixed potential regardless of pH. Its inner tube contains calomel and mercury, is immersed in outer tube containing saturated KCl. Electrical contact with test solution is through a ground joint or capillary leak *G*.

FIG. 134—ELECTROMETRIC METHOD. The potential produced by pH electrodes (see above) is measured by sensitive amplifier and self-balancing potentiometer. Circuit shown is that of Bailey Meter Co., using Beckman electrodes. Circuit contains resistance thermometer (not shown) for automatic temperature compensation. Potential of high-resistance glass halfcell vs. standard calomel halfcell is amplified electronically, then balanced vs. fixed voltage in d.c. potentiometer. Potentiometer battery is standardized periodically vs. standard cell *SC*, by switching *SC* into circuit instead of pH cell. Potentiometer output, if unbalanced, is converted to a.c., amplified, and applied to potentiometer-balancing motor *M*, which adjusts slide-wire *S* for rebalance. Position of *S* determines pen location, calibrated in pH. Range: Various electrodes cover various ranges from pH-0 to pH-14. Accuracy: 0.02 pH or better. Remarks: Used for measurement and control in numerous applications by practically all process industries. Controls reactions, measures product quality, controls flocculation and coagulation, controls waste effluents, etc.

FIG. 135—COLORIMETRIC METHOD. Inferential method of pH measurement is based on the fact that various indicators will give different color changes dependent on pH. Using a visual comparator, colors are then compared with color standards, principle of which is shown in the figure. Tubes 1, 2 and 3 hold color standard, distilled water and next-higher color standard, respectively. Tubes 4, 5 and 6 hold test material, material plus indicator, and test material, respectively. Standards are changed in tubes 1 and 3 until test color is matched. Range: 0.2-13.6 pH. Accuracy: 0.1 pH. Remarks: Used in laboratory and plant work wherever manual pH measurement is desired. Much less costly than electrometric equipment.



OXIDATION-REDUCTION POTENTIAL (Beckman Instruments, Inc., others). In "redox" reactions, negatively-charged electrons are transferred between reactants; e.g., ferrous ion loses an electron, becomes ferric (is oxidized or gains increased positive charge). Such a reduction does not necessarily involve presence of oxygen. Reduction is the reverse operation. Inert metal electrode vs. calomel reference electrode will develop a potential that shows the balance of oxidized vs. reduced ions in solution. Must be corrected for temperature and pH. Result is Eh. Remarks: Can be used both to follow the progress of redox reactions, and to control the addition of reagents. Equipment is the same as that for pH, except for substitution of gold or platinum electrode for glass electrode, and change in instrument calibration. This method is now being used in waste treatment, bleach production, pulp and paper bleaching. Suited for relatively high temperature, pressure.

14—Electrical Conductivity

FIG. 136—CONDUCTIVITY CELLS IN A.C. BRIDGE. Electrical conductivity of a solution is a measure of all ions present. Cell consists of two inert electrodes placed in solution, with impressed a.c. flow to avoid polarization. Connected in wheatstone-bridge circuit, this measures conductivity as resistance, in comparison with bridge resistor *R*. For temperature compensation, alternate method uses sealed reference-cell of same solution. Bridge may be self-balancing type (Section 24), often with cathode-ray null indicator (Industrial Instruments, Inc.). Range: From as low as 0.01 ppm. dissolved solids, to as high as oleum. Accuracy: Usually 1% of actual concentrations; but with precision methods, 0.1%. Remarks: Used mainly for detecting condenser-water leaks into condensate, determining exhaustion of deionizing beds. Also has process applications where strength of single-component solutions is to be measured. Can be used for recording, alarm, or both. Also suitable (Leeds & Northrup) for determining carry-over in steam from boilers and evaporators, by condensing steam.

GAS ANALYSIS BY WATER CONDUCTIVITY (Davis Instruments). Conductivity of distilled water is measured before and after its contact with gas sample. Circuit is like that of Fig. 136; a reference cell is used for distilled water, second cell for sample. Water flows through reference cell, absorber, sample cell. Range: Used only for gases that ionize in water. Remarks: Suitable for gases directly ionizable in water, or ionizable after being broken down by heat. Includes chlorinated hydrocarbons, carbon disulfide, chlorine, hydrogen sulfide, sulfur dioxide, hydrogen chloride, etc.

FIG. 137 — ELECTRODELESS CONDUCTIVITY MEASUREMENT (Industrial Instruments, Inc.). Liquid sample flows through piping that is surrounded by two torrodial coils. One coil is connected to a transmitter, which supplies a stable voltage in audio frequency range (60 cycles to 18 k.c.). Second coil is connected to receiver, and measures output voltage—which is proportional to conductivity of solution. Range: Conductivities from 0.001 to 10 mho/cm. Accuracy: 1% of full scale. Remarks: Suitable for solutions containing fibers, abrasive slurries, hot and highly conductive or extremely corrosive solutions.

15—Thermal Conductivity

FIG. 138—DOUBLE CELL, SINGLE-PASS TYPE. The heat loss from two identical hot wires (one in test gas, one in standard gas) is measured in terms of resistance change. Result shows relative thermal conductivity, which in many binary mixtures can be expressed as composition of test gas. Conductivity varies widely for various gases. Range: Under favorable conditions, 0-100% of one gas in another. Accuracy: High under favorable circumstances. Remarks: Widely used for binary gas mixtures such as hydrogen-nitrogen, hydrogen-carbon monoxide, air-carbon dioxide. Now being used as a measuring element in gas chromatography. (For multicomponent mixtures, see next method.)

DOUBLE CELL, DOUBLE-PASS TYPE. Multicomponent mixture to be analyzed is passed through the first cell of Fig. 138. Next, mixture is altered by burning, absorption, etc., so as to change the conductivity of the one component to be measured. Finally, mixture passes through second cell. Difference in conductivity is a measure of the wanted component's conductivity. Accuracy: Can be high under favorable circumstances. Remarks: Used, for example, in analysis for carbon dioxide mixed with air and carbon monoxide (in this case, the dioxide is absorbed after first pass). These methods may use a.c. rather than d.c. bridge circuit.

FOUR-CELL CONDUCTIVITY-CONVECTION TYPE (Mine Safety Appliances Co.). To give added sensitivity, this type uses a conventional cell (in which thermal conductivity is the main source of heat loss) in series with a larger-diameter cell (where both conductivity and convection heat losses occur). Larger cell loses heat faster, but the difference becomes greater as the thermal conductivity of the gas decreases. Method therefore amplifies the difference between, say, carbon dioxide and hydrogen. Range: Calibration possible over very narrow or very wide ranges. Accuracy: High. Remarks: By increased selectivity, it is said to be possible to analyze continuously for one component of a mixture without interference from other constituents. Hookup is similar to four-cell, single-pass type (see below), with one large- and one small-diameter cell on each side of bridge. Sample flows in parallel to one side, standard to other.

FOUR-CELL, SINGLE OR DOUBLE-PASS TYPE (Gow-Mac Instrument Co.). Same general method as Fig. 138, except that four cells are used, hooked up as the four arms of a wheatstone bridge. Range: Industrial gases suitable for thermal conductivity. Accuracy: High as 16 ppm. hydrogen in oxygen. Remarks: Analysis by either single or two-pass method. Double the usual number of cells increases the response.

16—Caloric Value, Combustible Content, and Explosibility

FIG. 139—CONTINUOUS GAS CALORIMETER (Cutler-Hammer, Inc.). Gas is burned at constant rate, transferring heat to metered flow of cooling air. Temperature rise of air is measured by resistance thermometers T_1 and T_2, temperature difference being recorded as calorific value by self-balancing wheatstone bridge circuit. Range: All fuel gases. Accuracy: High. Remarks: Used to record calorific value of fuel gases for inventory purposes, and to control mixing to standard calorific value.

FIG. 140—COMBUSTIBLE-GAS DETECTORS (Mine Safety Appliances Co., others). Heated, sensitized resistance wire in a bridge circuit is protected by metal gauze. If combustible gas in air contacts filament, then combustion raises temperature, changes resistance, and is detected by bridge. Calibrated for particular gas as % of exposive limit. Range: Any combustible gas or vapor. Accuracy: High. Remarks: Used for detecting dangerous limits of solvent vapors, fuel gases, sewage gases, gasoline vapor.

COMBUSTIBLE-GAS ALARM (Mine Safety Appliances Co., others). Similar in principle to Fig. 140, except that instrument is designed for continuous sample-taking and has an automatic alarm that signals unsafe condition. Sealed reference-cell (see Section 15) adds to accuracy of circuit. Range: All industrial combustible gases. Accuracy: High. Remarks: In explosionproof case, unit is used for continuous monitoring of hazardous areas. Calibrated for particular gases, but will detect any other combustible gas or vapor that may be present.

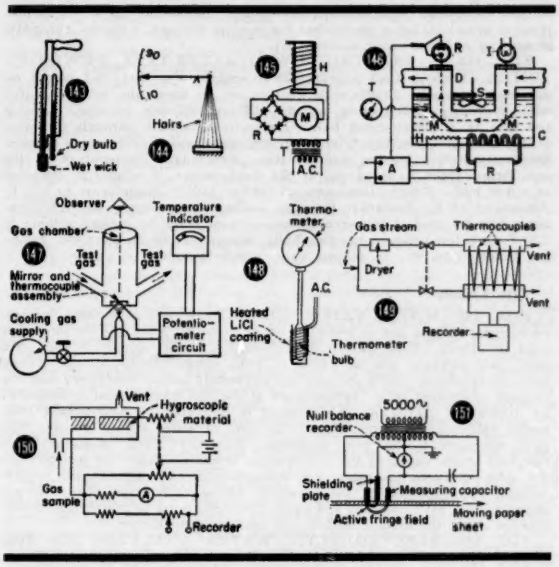
FIG. 141—EXPLOSIVE-GAS RECORDER, THERMOCOUPLE TYPE (Davis Instruments). Similar in principle to type described above, except that the test and standard gas filaments are heated by a.c. while their temperature rise is measured by thermocouples bonded to the heaters. Combustion raises the heaters' temperature as well as thermocouples'. The latter (opposing) action produces voltage proportional to explosibility. Range: Usual ranges of industrial explosive gases. Accuracy: High. Remarks: Has an advantage over the Wheatstone-bridge method, since gradual loss of Pt from the heaters does not cause zero drift of instrument. Heater temperature remains substantially constant despite loss.

FIG. 142—COMBUSTIBLE ANALYZER (Bailey Meter Co.). Measured volume of air is added to sample gas, which is then burned on a sensitized Pt filament. Temperature rise is measured as the resistance change in an a.c. bridge, recorded as % combustibles. Range: Minimum span is 5% combustibles; maximum, 25%. Accuracy: ¼% actual at lower ranges, 2% scale at higher levels. Remarks: Used for measuring combustibles in furnaces, kilns, chemical processes. Unit can both record measurements and operate alarms.

17—Humidity of Gases

(a) Wet-Bulb Depression

FIG. 143—SLING PSYCHROMETER. Based on measurement of wet-bulb depression. Two thermometers are fastened together. One measures dry-bulb; the other, covered with a water-saturated wick, measures wet-bulb—provided the sling is whirled to produce rapid air flow for maximum evaporative cooling. From psychrometric tables, the relative humidity and dewpoint can be determined. Range: 0-100% Relative Humidity (R.H.). Accuracy: Up to about 1%. Remarks: Most accurate, simple and cheap device for measuring relative humidity of air.



RECORDING PSYCHROMETER. Principle is the same as that of sling psychrometer, except that bulbs of a two-pen recording thermometer are installed in an air stream of at least 900 ft./min. Wet-bulb wick is kept saturated by a water reservoir. Range: 0-100% R.H. Accuracy: 1% or better. Remarks: Probably the most used method for recording wet-bulb and dry-bulb temperatures for industrial humidity determination. Hazard: wet-bulb may run dry.

DIRECT-RECORDING PSYCHROMETER (Leeds & Northrup Co.). Measures wet and dry-bulb temperatures, as above, except that resistance thermometers are used. Bridge circuit incorporates novel arrangement, reading directly in R.H. Recorder has two superimposed bridge circuits; one for wet, one for dry-bulb. If wet and dry-bulb temperatures are plotted against each other, they fall on a constant-R.H. line through the origin; all combinations on this line are of the same R.H. Hence, recorder compares the measurements, finds which line they fall on, and indicates the result as R.H. Range: 10-100% R.H. Accuracy: 1.5% R.H. or less. Remarks: Saves computation of relative humidity from wet and dry-bulb readings. Simplifies automatic control.

(b) Hygrometers

FIG. 144—DIMENSIONAL-CHANGE HYGROMETERS. Various organic materials change in linear (or volume) dimensions with changes in relative humidity. Among them are human hair, which makes one of the most accurate hygrometers; various woods; animal membranes. If wood shavings are cemented to a screen-wire spring and coiled like a bimetallic thermometer (Fig. 1), the result is a simple direct-reading indicator. Range: 20-90% R.H. Accuracy: 2% in best units, but generally rather poor. Remarks: Advantage is direct reading in R.H. Slow response, somewhat temperature-sensitive.

FIG. 145—ELECTRICAL-RESISTANCE HYGROMETERS (Brown, others). Originally developed by National Bureau of Standards, but now made by several firms. Double-wire winding on a light insulator is coated with hygroscopic film containing lithium chloride. Film becomes increasingly conductive as its equilibrium moisture-content increases. Hence, ambient humidity determines the coating's conductivity; and conductivity, in turn, governs flow of current between the wires. Range: 35-93% R.H.; 50-120 F. dry-bulb temperature. Accuracy: 1.5% or better. Remarks: Rapid response and good accuracy are main advantages. An a.c. input may be used, measured as d.c. by rectifier bridge. Or the element's resistance can be measured in a wheatstone-bridge circuit. Can be self-compensating for temperature.

(c) Dewpoint

FIG. 146—MIRROR-TYPE DEWPOINT RECORDER (General Electric, others). Mirror M, in contact with flowing gas, is cooled to condense the vapor. Light passing through duct D from source I to photocell P is reduced as a dew forms. Meter A then starts a heater H to evaporate dew. When light again increases, refrigerator R cools bath, repeating cycle. Temperature shows peaks and valleys, the valleys being dewpoint temperature. Only valleys are recorded. Range: From —100 F. to 110 F. Accuracy: 3° F. Remarks: Can measure extremely low dewpoints; hence, is used chiefly for determining moisture content of industrial gases.

FIG. 147—DEWPOINT INDICATOR (Weighing & Control Components, Inc.). Test gas enters chamber and impinges directly on thin metallic mirror, where dew spot is formed. Cooling gas (carbon dioxide or other) is directed against bottom of mirror to cool surface down to dewpoint temperature. Thermocouple fastened to mirror is electrically connected to potentiometer circuit. Operator visually notes dew spot while maintaining balance of potentiometer and increasing cooling gas flow. Range: Dewpoints from ambient to —100 F. Accuracy: ±5 F. Remarks: Similar principle, using phototubes for sensing dewspot, provides automatic measuring and recording at dewpoint.

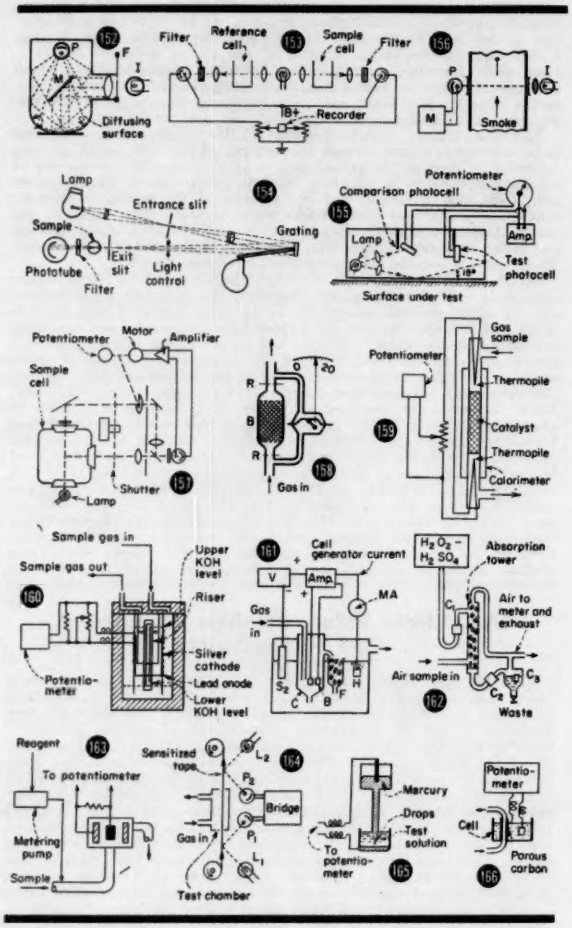
FIG. 148 — ELECTRIC HYGROMETER-TYPE DEWPOINT METER (Foxboro Co.) superficially resembles Fig. 145, but works on different principle. Double-wire winding on an insulating tube is coated with hygroscopic conducting coating (lithium chloride solution). Inside the tube is a thermometer bulb. Low-voltage current through the wire heats the coating, thereby driving out moisture until equilibrium is reached between moisture leaving and moisture returning. Temperature of the equilibrium point, as measured by the thermometer, is related to dewpoint of air at bulb. Range: Dewpoints of —50 to 140 F. at ambients to 220 F. Accuracy: 1° F. Remarks: Requires neither water supply nor refrigeration. Can be used at higher ambients without error by cooling sample to 220 F. or below before contacting bulb. Reads directly to dewpoint, grains per standard cu. ft., or percent water vapor by volume.

(d) Other

FIG. 149—WATER-VAPOR RECORDER measures heat energy exchanged when a gas is adsorbed on or desorbed from the surface of a solid adsorbent (Mine Safety Appliances Co.). Gas sample is split into two equal streams, one of which is dried completely by a regenerative adsorption column. Split streams are alternately passed every two minutes through adsorption cells. Temperature at the equilibrium point is measured by differential thermopile. Cell output is measured by peak-to-peak voltmeter, calibrated to record directly in ppm. of water vapor. Range: 0-50 ppm. minimum; 0-5,000 ppm. maximum. Accuracy: ±1%. Remarks: Unit monitors water vapor in hydrocarbon-gas streams. Since the gas streams are split, alternate adsorption and desorption in each detector cell is permitted, thus regenerating the desiccant during each cycle. The two gas streams must have constant and equal flow, and must be maintained a few degrees above the highest anticipated ambient temperature.

FIG. 150—ELECTROLYCTIC WATER ANALYZER (Du Pont design, but made by Manufacturers Engineering & Equipment Corp., others). Water vapor in gas stream is continuously passed over—and absorbed onto—a film of partially hydrated phosphorus pentoxide. The absorbed water is quantitatively electrolyzed between platinum electrodes in the detector cell. Current required for electrolysis is directly proportional to the absorbed water (Faraday's Law). Meter *A*, in series with the cell, reads a value proportional to the water content of gas stream. Ranges: 0-30 ppm.; 0-100 ppm.; 0-300 ppm.; and 0-1,000 ppm. Accuracy: ±5%. Remarks: Detects water in various inorganic gases, hydrocarbon gases and vapors, fluorinated hydrocarbons. Basic compounds such as ammonia, and organic compounds such as methanol, cause interference. Flow must be metered for specific gases.

PROCESS-MOISTURE MONITOR (Consolidated Electrodynamics). Instrument measures moisture content of liquids by stripping water from the sample with a dry gas and passing water vapor and stripping gas to electrolytic cell. Water vapor is detected in the cell by a method similar to that shown in Fig. 150. Operates with sample pressures from 10-100 psig. Range: 10-1,000 ppm., in five steps. Accuracy: 10% of full scale on any range. Remarks: For continuous measurement of water in liquid streams.



18—Moisture Content of Solids

RESISTANCE METERS (Tagliabue, others). Resistance of massive solids is read between prongs that are mounted a fixed distance apart and thrust into the material to be measured. Resistance of pulverized materials is read by applying standard compression between plates, measuring resistance across plates. Uses wheatstone-bridge circuit and indicator. Remarks: Used for powders, lumber, leather, tobacco and similar materials. Calibrated against materials of known moisture content.

DIELECTRIC-CONSTANT METER (Tagliabue). Since water has 15 to 20 times the dielectric constant of most materials, small changes in water content mean relatively large dielectric changes. Weighed material is put into test condenser, and oscillation frequency of test-cell circuit is set to standard frequency as produced in a second, crystal-controlled oscillating circuit. Null position represents moisture content. Range: Likely range of moisture content in commercial materials. Accuracy: High. Remarks: Used chiefly on seeds, grains and powdered chemicals.

FIG. 151—DIELECTRIC-CONSTANT MOVING-WEB METER (Foxboro Co.). A box, mounted over a moving web of moist material, contains hygroscopic dielectric between condenser plates. Air in the box and in the dielectric attains moisture equilibrium with web material. This equilibrium—and hence moisture content of the web—is determined as capacitance in a high-frequency bridge. Remarks: Used extensively in paper mills to measure moisture content of paper as it progresses through a paper machine.

19—Optical Properties

(a) Color

FIG. 152—COLOR COMPARATORS are used to obtain visual match of colors. First, a standard material is put at *S* and response of photocell *P* is obtained with white, red, green and blue light (obtained by filters at *F* from source *I*). Then sample is put through same routine. Comparable response should give visual match. Remarks: Used in matching paints, dyes, paper colors and the like. Can also compare transmission of a color.

PHOTOELECTRIC COLORIMETERS. Many types are made, but in general they compare transmission of light of various colors (produced with monochromatic filters) through a sample and a standard. Light from an integrating sphere may be passed alternately through the sample and standard by use of a light chopper, in which case the comparative transmission is read with a photo-multiplier tube. System can be balanced to nonpulsating output of photomultiplier by reducing the light that reaches the standard. Remarks: Used where exact transmission (or reflectance) of certain colors is needed for matching or for permanent record, but complete spectrophotometric curve is not needed.

FIG. 153—PHOTOELECTRIC COLORIMETERS (Milton Roy Co., others) use two similar photocells. Light is passed through the sample to one cell, while some of the same light is sent unobstructed to the reference cell. Cell outputs are then compared in the recorder circuit. Outputs are balanced, and relative transmissions recorded. Remarks: Can be used with auxiliary equipment involving colorimetric titrations for the detection in ppm. range of many compounds (e.g., silica or total hardness in water, etc.).

RECORDING SPECTROPHOTOMETER (General Electric) differs basically from filter photometers and comparators. Unit has a spectrometer-type monochromator in which monochromatic light of any desired wavelength from 400 to 700 millimicrons is produced by dispersion with prisms and a slit. This light is passed alternately through a sample and a standard, chopped to produce an a.c. (if unbalanced), and then is balanced by a light-polarizing prism, position of which is recorded as % transmission vs. wavelength. Range: Wavelengths from 400 to 700 millimicrons (1,000 is possible). Accuracy: Results reproducible to 0.2%. Remarks: Unit is used to color-control all types of colored products, enabling complete colorimetric analysis to be made and recorded. Operates automatically.

FIG. 154—DIFFRACTION-GRATING SPECTROPHOTOMETER (Bausch & Lomb) produces monochromatic light by using 600 grooves per mm. grating. Dispersion of grating is linear; output, constant. Range:

375-650 millimicrons. Remarks: In colorimetry applications, unit reads optical density or percent transmittance; in spectrophotometry, it reads absorption. Grating is adjustable to cover specific range.

(b) Other

FIG. 155—GLOSS RECORDER (Gardner Laboratory, Inc.) measures reflectance, brightness, etc. Available in various types for measuring gloss at 20, 45, 60, 75 and 85° angles. Type shown is for beam striking surface at 75° from vertical; has one light source, two photocells. One beam (reference) is concentrated directly on first photocell. Second beam is projected on surface to be measured, reflected onto second photocell. Cell outputs are compared by a null-balance potentiometer recorder that records in % reflectance. Standard cell is periodically adjusted to 100% reflectance. Accuracy: Precision of two scale units. Remarks: Used in measuring reflectance of glossy products such as coated and supercalendered paper, enamels, paints, plastics.

(c) Turbidity, Opacity

FIG. 156—SMOKE AND FUME-DENSITY METER (Photomation, Inc., others). Type shown uses photocell to measure light absorption by smoke in a stack. Bailey Meter Co. uses a hermetically sealed bolometer (resistance thermometer) to measure reduction in the amount of heat received from a sealed-beam spotlight. Null-balance recorder is compensated for temperature. Range: Various; 0 to complete cutoff. Remarks: Used to monitor smokestacks and to measure density of white water in paper mills. May be applied to automatic combustion control.

FIG. 157—PHOTOELECTRIC TURBIDIMETER (Baird-Atomic, Inc., others). Light is transmitted by the liquid in a sample cell; this light is continuously compared with the light scattered by suspended particles in the stream. Phototube output, measured by recording potentiometer, varies as the light is more or less cut off by suspended particles. Range: Various ranges, such as 0.05-250 ppm. Accuracy: ±2%. Remarks: Used for monitoring turbidity, color or other light-absorption properties of process solutions.

20—Composition by Chemical Reaction

ORSAT GAS ANALYZERS operate by absorbing various gaseous components, measuring their volume at standard pressure. Range: 0-20% CO_2 (any range is theoretically possible). Accuracy: High. Remarks: Used chiefly for measuring carbon dioxide in stack gas (i.e., combustion control).

FIG. 158—GAS ANALYSIS BY PRESSURE DROP. Gas passes through a restriction, an absorption chamber, and another restriction. Differential pressure across the restrictions is a measure of % gas absorbed. Hays Corp.'s analyzer measures the volume of residual gas after carbon dioxide has been absorbed; this residual volume is then converted into an equivalent air pressure. Air pressure operates through bellows to actuate recorder. Range: Approximately 0-50%. Accuracy: Moderate. Remarks: Has been used chiefly for carbon dioxide.

FIG. 159—OXYGEN ANALYZER (Engelhard Industries, Inc.). Oxygen as an impurity in gas streams is catalytically oxidized by excess hydrogen in a calorimeter. Heat liberated is directly proportional to the oxygen content. A thermopile, with cold junction located ahead of the catalyst and hot junction placed where the gas stream emerges from catalyst chamber, indicates temperature rise. Range: 0.001 to 1% oxygen; 0.002 to 2% hydrogen. Accuracy: ±2%. Remarks: Unit detects small quantities of oxygen in inert gases, carbon dioxide, hydrogen or saturated hydrocarbon gases. Hydrogen and oxygen for the analysis are generated by an electrolytic cell within the instrument.

COLORIMETRIC DIFFERENTIAL PHOTOMETER (Consolidated Electrodynamics Corp.) also detects trace amounts of oxygen in gas streams. An oxygen-sensitive reagent produces a proportional color change in the gas sample containing oxygen. Colorimeter similar to that shown in Fig. 153 measures the optical transmittance between the oxidized and reduced reagent, and determines the amount of oxygen present. Range: 0-50 ppm.; 0-1,000 ppm. Accuracy: ±2%. Remarks: Detects trace amounts of oxygen in polymerization processes, hydrogen and inert gases.

FIG. 160—ELECTROLYTIC OXYGEN ANALYZER (Beckman Instruments, Inc.; Engelhard Industries, Inc.). Oxygen in a gas stream is dissolved in potassium-hydroxide solution that circulates in a thin film over a lead anode. A silver electrode, inert to the electrolyte, acts as the cathode. Electrochemical reaction at the cathode converts oxygen to hydroxyl ions, causing flow of current proportional to the partial pressure of oxygen in the gas. Engelhard uses cadmium anode. Range: 0-500 ppm. Accuracy: ±5%. Remarks: Unit provides continuous monitoring of oxygen in inert gases, hydrogen, saturated and unsaturated gases.

POTENTIOMETRIC TITRATION. Neutralization and other endpoints are determined by suitable indicating and reference electrodes. Potentiometer controls cutoff. Range: Any. Accuracy: 0.5% or better. Remarks: Used in laboratory work, but could be adapted to automatic analysis and control.

FIG. 161—BROMINE TITRATION FOR SULFUR GASES (Tritrilog, Consolidated Electrodynamics). Automatic titrator for sulfur gases. Gas enters titration cell *C*, where it is titrated with bromine generated by current between electrodes *H* and *B*. Production of bromine is controlled by: (a) the sensing electrodes S_1 and S_2, and (b) the opposed-reference voltage *V* (calomel electrode). An excess of sulfur will increase both potential and output of d.c. amplifier *A*, thus increasing bromine production to restore bromine-sulfur balance. Sulfur content is recorded in terms of electrolysis current by meter *MA*. Range: Concentration as low as 0.1 ppm. Accuracy: High. Remarks: Used to record low concentrations of sulfur-containing gases such as mustard, mercaptans, SO_2, H_2S.

FIG. 162—SULFUR DIOXIDE BY ELECTRICAL CONDUCTIVITY (Thomas Autometer, L & N). SO_2 in air is absorbed in sulfuric acid and hydrogen peroxide. Electric conductivity of the solution is measured before and after absorption by conductivity cells C_1 and C_2. Any increase in conductivity is caused by SO_2 being converted to sulfate, and is recorded as % SO_2. The spent solution accumulates in a reservoir, and is measured periodically by C_3 for integration of SO_2. Range: 0-5 ppm. SO_2. Accuracy: Better than 0.1 ppm. Remarks: Used in determining low concentrations of SO_2 in the atmosphere.

FIG. 163—RESIDUAL-CHLORINE ANALYZER—Fischer & Porter, Wallace & Tiernan). Water sample flows between cell electrodes that are of different metal alloys. Polarization of noble-metal electrode prevents current flow in absence of oxidizing agents. Presence of a trace of chlorine or iodine causes partial oxidation of polarizing layer, causing current to flow between electrodes. Current is proportional to chlorine or iodine concentration. Range: 0-20 ppm., in two steps. Accuracy: ±5%. Remarks: Records and controls the chlorine content of water supplies, or effluent from waste-treatment plant.

FIG. 164 — HYDROGEN-SULFIDE CONTENT BY COLOR CHANGE (Minneapolis-Honeywell). Photocells P_1 and P_2 continuously scan a sensitized tape for darkening of lead acetate by H_2S. Cells are connected into bridge circuit *B* for continuous record as H_2S. Range: Suitable for low concentrations. Accuracy: High. Remarks: Same principle can be applied to other gases, where suitable color change is available. Similar method used by General Electric for Hg vapor.

GAS TESTERS (Mine Safety Appliances Co.). Visual color-change testers are made for CO, aromatic hydrocarbons, and H_2S, using suitable reagents impregnated into silica gel. Color change compared with color scale gives a % reading. Range: CO from 10 to 1,000 ppm.; H_2S from 25 to 400 ppm. Remarks: This is a lightweight, portable unit for manual use in detecting conditions within working areas and process vessels.

FIG. 165—POLARIGRAPH uses dropping mercury as a continously renewable electrode on which various ions will plate out as the potential increases. The record forms a steplike curve that indicates substances by position of step, quantity by height. Range: For trace-element analysis as well as large-concentration investigation. Accuracy: Measures down to 1/10,000 of 1%. Remarks: Primarily a laboratory instrument for quick, automatic analysis, especially of trace elements in plating, organic chemicals, lube oils and explosives.

FIG. 166—POLARIZING-CELL OXYGEN ANALYZER (Mine Safety Appliances Co.). Gas passes through a porous-carbon tube electrode into a cell that contains a special electrolyte and a second, metallic electrode. Cell generates current, which polarizes the carbon electrode. Oxygen diffuses through the carbon, thus depolarizing the cell. Current output depends on % oxygen, which a potentiometer records. Range: Various, such as 0-1.0%, 0-25%. Accuracy: 2% of scale. Remarks: General-use instrument for recording oxygen concentration.

21—Composition by Spectroscopy

(a) Emission

FIG. 167—ARC OR SPARK (EMISSION) SPECTROSCOPE. At high temperature of arc or spark, material to be analyzed gives off characteristic radiations at different wave lengths. Light can be dispersed by prism or diffraction grating, producing a characteristic line spectrum that can either be photographed or split into individual lines by a slit, for viewing. Range: About 2,000 to about 9,000 Angstrom units. Accuracy: Depends on quality of optics. Remarks: Method is used for element identification in chemical analysis (especially of metals and alloys) and astronomy. Can identify trace elements down to billionths of grams. Most emission spectroscopy is done with a grating spectrograph.

FIG. 168—EMISSION SPECTROGRAPH, DIRECT-READING (Baird-Atomic, Bausch & Lomb, others). Unit has a concave diffraction-grating spectrometer with spark or arc source, and movable exit slits. Light passing through slits is focused by concave mirrors onto several photomultiplier tubes, which charge the condensers in proportion to the intensity of each line (i.e., concentration of element). Condenser charges are measured by electric clocks (one for each element) calibrated in % of element present. Range: 2,800-4,300 Angstrom units (second-order spectrum). Remarks: Used in metal and alloy analysis for a number of elements. Extremely fast—about five minutes from sampling to report.

FIG. 169—FLAME PHOTOMETERS (Perkin-Elmer Corp., others). A sample when sprayed into a gas flame will give off its own characteristic light. This light is passed into entrance slit E_1 and through an optical system of prisms and lenses to beam splitter, where part of it is shot out of a movable exit slit E_2 to photocells P_1 and P_2. Other part is sent through fixed slit E_3 to standardizing cell P_3. Red and blue-sensitive cells measure the intensity of characteristic lines, with the aid of movable slit E_2. Range: 3 to 1,000 ppm., depending on metal (Na, K, Li, Ca, Sr, others). Accuracy: 1-2%. Remarks: Primarily a laboratory instrument for rapid analysis of metals in mixtures. Good for trace elements. Time is less than 2 min./element.

(b) Infrared Absorption (Dispersive Types)

FIG. 170—INFRARED-ABSORPTION SPECTROMETER, SINGLE-BEAM (Perkin-Elmer Corp., others). Radiation from an SiC glower is focused by mirrors onto a sample cell before being passed through entrance slit to collimating parabolic mirror that reflects onto prism. Radiation is dispersed by the prism and reflected by a movable-wavelength mirror back through the prism, the parabolic mirror, and eventually through the exit slit and adjacent mirrors to a thermocouple. Intensity of narrow frequency band is selected by wavelength mirror and measured. As spectrum is scanned, recorder plots intensity vs. wavelength. Range: 2-40 microns, depending on prism material (2-15 microns with NaCl prism). Accuracy: High. Remarks: Used for analysis of organic materials in solid, liquid or vapor state. Same principle has been used in a continuous product-stream recorder for six components measured in a five-minute cycle.

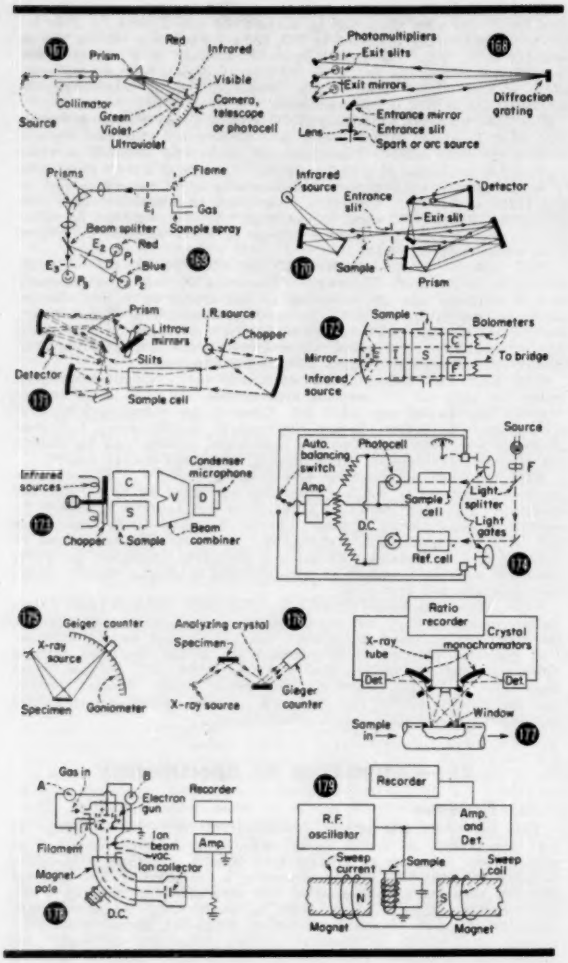


FIG. 171 — INFRARED-ABSORPTION PLANT-STREAM ANALYZER (Perkin-Elmer Corp.). Used for continuous analysis of a single component in process stream. Unit is set to measure any two infrared wavelengths simultaneously: one is in the region where a component of interest absorbs strongly; the other, where it does not. The ratio of two measurements are reported as % of component. Source radiation is chopped mechanically into two beams 180° out of phase and of slightly different paths. These beams alternately pass through sample cell and through a reflecting system and slit. They then pass through a prism and are reflected by separate Littrow mirrors along different paths back through the prism and reflecting system to a detector thermocouple. If beams are alike, there is no signal; if they are different (due to different absorption), a.c. results, is amplified and drives a servo to attenuate and null the reference beam. Attenuator position is reported as sample composition. Range: Depends on application. Accuracy: Also depends on application, but reproducibility is usually within 1% of scale. Remarks: Used in plant liquid or gas streams for analysis or determining course of a reaction. Suitable for liquids requiring extremely thin sample cells.

INFRARED ABSORPTION SPECTROMETER, DOUBLE-BEAM (Baird-Atomic, others). Essentially similar in principle to type described in Fig. 173, except that initial beam is split to pass through both sample and a compensator cell or standard cell. Any unbalance is nulled, recorded as % absorption vs. wavelength. Range: Full useful range of optics. Accuracy: High. Remarks: Used mainly in high-precision organic research.

(c) Infrared Absorption (Nondispersive Types)

FIG. 172 — INFRARED ANALYZER, NONSELECTIVE OR NEGATIVE TYPE (Baird-Atomic, others). Where spectrometers use monochromatic radiation, analyzers use all radiation from about 1 to 15 microns. There are two general types: nonselective, which uses two steady beams; and selective (below), which uses chopped radiation. Nonselective (Fig. 175) passes radiation through two lines, one containing sample *S* and filter cell *F*, the other containing sample *S* and compensator cell *C*. Filter contains 100% of the component sought; compensator contains other gases in the mixture. Interference cell *I* is sometimes used to desensitize interfering gas. Comparison of radiation received by bolometers is indicative of % of the gas being sought, as long as cells are properly sensitized. Range: Single hydrocarbon vapors in certain combinations. Also other gases. Accuracy: High. Remarks: Used for continuous plant-stream analysis (for example, on methane in illuminating gas, acetone in air, isobutane in normal butane and other hydrocarbons). Also can be used for sulfur dioxide, water vapor in low concentrations, carbondioxide and monoxide, etc.

FIG. 173—INFRARED ANALYZER, SELECTIVE OR POSITIVE (LUFT) TYPE (Mine Safety Appliances Co., others). Similar to nonselective type in Fig. 175. Wide range of radiation. However, this unit differs in that its beams alternate through two sides; the sample *S* and compensator cell *C* are not in series; and a different type of detector is used. Detector is a condenser microphone receiving pressure fluctuation from alternating beams combined in *V*, which is filled with nonabsorbing gases. *D* is filled with gas analyzed for, compensator *C* usually with nonabsorbing gas. Null balance adjusts source on compensator side to give equal response on both sides, difference in radiation being recorded as % of gas analyzed for. Range: Single gases including hydrocarbon vapors in certain combinations. Accuracy: High. Remarks: Used for continuous plant-stream analysis. Similar to nonselective type.

THREE-BEAM INFRARED ANALYZER, POSITIVE TYPE (Tri-Non, Perkin-Elmer Corp.). Essentially similar to Fig. 173, except that nulling is accomplished by optical attenuator. Severe interference can be compensated by using a third beam.

(d) Ultraviolet and X-Ray Absorption

ULTRAVIOLET SPECTROMETER. Radiation from a hydrogen-discharge lamp passes through entrance slit to collimating mirror, thence through quartz prism to reflecting backing, and back through the prism and collimating mirror to exit slit above entrance. Passing through sample cell, it reaches phototube where intensity is measured for various wavelengths. Rotating quartz prism supplies monochromatic radiation of various wavelengths from 0.2-1.0 microns. Recorder plots transmission intensity vs. wavelength. Range: 0.2-1.0 microns. Accuracy: Reproducible to 0.02 millimicrons. Remarks: Used to analyze liquid and gaseous materials such as vitamin A, butadiene, toluene molecules containing benzene rings, ethylene, carbonyl structures, etc. With flame attachment, unit becomes a flame photometer.

FIG. 174—NONDISPERSIVE ULTRAVIOLET ANALYZER (Manufacturers Engineering & Equipment Co., Hallikainen, others). In Du Pont design shown, light of desired wavelength (0.22-1.2 microns) is selected by optical filter *F*, then split into two beams. One beam passes through sample cell, the other through reference cell. Use of two beams eliminates effect of cell-window deposits by having thin section of the material to be analyzed acting as reference material, thicker section as effective sample. Sample passes through both beams. Unabsorbed light passed through cells falls on opposed photocells in bridge circuit, any unbalance driving a servo motor that moves light gate into sample path to restore balance. Where window fouling is unlikely, only a single cell in sample path is used, the reference beam falling directly on its phototube. Range: 0-100% composition, down to 0-1 ppm. for some materials. Accuracy: High. Remarks: Less selective but more sensitive than infrared analyzers. Used in determining composition of organics, chlorine, sulfur dioxide, nitrogen dioxide, etc.

X-RAY PHOTOMETER (General Electric). X-radiation is passed through sample and partially absorbed. Transmission is recorded as % of unknown compared with standard. Range: Unit operates on various chemicals in presence of others. Accuracy: 0.2%. Remarks: Analysis is independent of the physical form of material analyzed. Used to detect sulfur in plastics and oils, tetraethyl lead in gasoline.

(e) Fluorescence and Diffraction

FIG. 175—X-RAY DIFFRACTION SPECTROMETER (Philips Electronics, Inc.). X-ray beam strikes sample, gives off a cone of secondary rays, intensity of which varies with atomic structure at different radii. Can be photographed to give characteristic concentric-ring patterns. For recording, a cross section of the diffraction cone is scanned by a Geiger counter moving along an arc (GONIOMETER). Range: Unlimited. No two materials show identical patterns. Accuracy: High. Remarks: Used in atomic-structure study and in identification of materials by comparison with known patterns. Since crystal structure is shown, unit can be used to distinguish—for example—between rutile and anatase phases of titanium dioxide.

ELECTRON DIFFRACTION. Similar to X-ray diffraction. Electron beam directed on sample produces a diffraction pattern that can be photographed. Range: Unit is designed to study thin films of ceramics, metals, plastics. Accuracy: High. Remarks: X-ray diffraction operates on internal structures; this unit, on surfaces.

FIG. 176—X-RAY FLUORESCENCE SPECTROMETER (Philips Electronics, Inc.). X-radiation causes some elements to give off characteristic individual radiations. These are collimated, analyzed by a crystal that, by its position, reflects individual radiations at specific angles. Intensities are measured by Geiger-counter goniometer. Range: Unit analyzes for elements. Accuracy: High. Remarks: Unlike X-ray diffraction, this method gives results that are characteristic of elements present in sample (X-ray diffraction deals with atomic structure). Suitable for metals, alloys, minerals, chemicals, mixtures and compounds.

FIG 177—X-RAY-FLUORESCENCE CONTINUOUS ANALYZER (Applied Research Laboratories). This method, originally used for control of tin-plate thickness, has been adapted to continuous solid or liquid streams. X-rays falling on the sample will produce characteristic radiations that are picked up by curved crystal monochromators. Reference monochromator diffracts only scattered radiation of a chosen wavelength, while the other monochromator diffracts the wavelength characteristic of

element being analyzed. Diffracted beams fall on separate Geiger counters, the ratio of whose outputs is recorded as concentration. Range: Used for elements of atomic number 19 (potassium) and higher. Accuracy: Highly selective. Remarks: Various analyses are possible, such as of metals in ores, plating solutions, catalysts.

(f) Mass Spectrometry

FIG. 178—MASS SPECTROMETER, CONTINUOUS-SPECTRUM TYPE. High-velocity electrons are produced between a filament and plate by electron-accelerating voltage *A*. Specimen gas at low pressure enters a tube, where the high-velocity electrons strike specimen-gas molecules, producing ionized molecules and molecular fragments that are accelerated by voltage *B*. Ions enter field of a magnet, which curves their paths proportional to mass. Individual masses can be focused by varying ion-accelerating field, forcing them to enter a slit and to discharge at ion collector. Ion current is amplified and recorded vs. accelerating voltage in terms of mass number. Different materials give characteristic mass peaks that are analyzed mathematically to find composition. Range: Unit analyzes materials that can be vaporized. Mass numbers from 1 to 300. Accuracy: Very high. Remarks: Coming into use in analytical product control of various kinds, both organic and inorganic. Uses of the unit include isotope tracer work, microanalysis. Peak heights define concentration.

MASS SPECTROMETER, RESTRICTED-SPAN TYPE. (Consolidated Electrodynamics Corp.). Similar in principle to above, but designed to scan a limited number of mass peaks for continuous product analysis. Range: Can be tuned to limited number of desired characteristic peaks. Remarks: Unit is used for identification and estimation, in metals and other solids, of impurities whose abundance is 0.1 ppm, or less. Also used for identification of materials by precise measurement of their molecular weight, and for study of molecular weights and structures of greases and polymers.

MASS SPECTROMETER, LEAK-DETECTOR TYPE. Simplified mass spectrometer is tuned to helium and used with a helium gas probe to locate leaks in pressure systems quickly. Range: For leaks too small for other methods. Accuracy: High. Remarks: First used in testing tightness of equipment in atomic bomb plants.

(g) Radio-Frequency Spectrometry

MICROWAVE ABSORPTION. Microwaves in the range 17-28,000 megacycles are sent through wave-guide tube, where gas absorption takes place. Emergent energy is monitored by a crystal detector, amplified and put on oscilloscope. Absorption at various frequency bands (about 50 mc. wide) is characteristic of various materials. Range: High precision. Remarks: Laboratory method. Too complex at present time for plant use. No commercial equipment available.

FIG. 179—NUCLEAR MAGNETIC RESONANCE (Schlumberger Well Surveying Co., Varian Associates, others). About 100 element isotopes are capable of absorbing radio-frequency (r.f.) energy in a magnetic field, due to magnetic moment and spin of atomic nucleus. In magnetic field, these act as miniature gyroscopes with a definite frequency. Sample tube in field of magnet is surrounded by a coil supplied by an r.f. generator. By sweeping a magnet current through the nuclear-resonant value, energy absorption occurs. Plot of energy absorption vs. magnetic field strength gives a characteristic spectrum. Area under each peak is a measure of the quantity of the particular nucleus present. Accuracy: 0.1% or better. Remarks: Accurate measurement of moisture in solids, even those containing hydrogen. Used for product identification in petroleum and chemical industries (detecting H, F, Li, P), and for identifying groups in complex molecules.

ELECTRON PARAMAGNETIC RESONANCE (Varian Associates). If an electron has both a magnetic moment along its own spin axis, and also a moment associated with its circulation in an atomic orbit, the electron will possess a total magnetic moment equal to the vector sum of these magnetic moments. Ratio of total moment to spin value is constant for given atom and environment. Since ratio varies for different atoms and environments, and since local magnetic fields depend on the structure of matter, it is possible to achieve spectral separation and study by this method. Detection of spectra is analagous to the method described by Fig. 179, but resonant cavity and microwave oscillator are used in this unit. Range: Applicable substances, such as for electrons in unfilled conduction bands, free radicals, impurities in semiconductors.

22—Composition by Other Physical Properties

(a) Oxygen by Magnetic Susceptibility

FIG. 180—MAGNETIC SUSCEPTIBILITY, NONUNIFORM-FIELD TYPE (Beckman Instruments, Inc.). Except for NO, oxygen is unique among gases in being attracted into magnetic field. A light test body tends to be pushed out of a nonuniform magnetic field if 0_2 is present. Displacement increases with 0_2 concentration, and can be measured with light rays on a scale. Null-balance method can also be used to record. Here, a plate with fixed d.c. potential draws a charged test body back to zero position when balance bridge applies proper charge. Balance bridge operates from light beam on photocells P_1 or P_2 as test-body position changes. Bridge balance is therefore a measure of 0_2 concentration. Range: From a few ppm. of 0_2 to 100%. Accuracy: 1% for ranges over 1% 0_2. Remarks: Used specifically for analyzing gas mixtures for oxygen.

FIG. 181—LOW-RANGE OXYGEN ANALYZER (Hays Corp.). Two electrically heated nickel windings are wound on the outside of a horizontal glass tube. Left-hand winding is placed between the poles of permanent magnet. Sample gas flowing through ring is attracted into glass tube by the magnetic field. This gas is heated by left winding, which decreases magnetic susceptibility of oxygen in gas. Cooler gas entering the tube pushes the heated gas out of magnetic field to produce continuous gas flow from left to right. Movement of gas cools left-hand winding; heats right-hand winding. Resulting temperature difference unbalances a wheatstone bridge, producing voltage unbalance in circuit. This unbalance is proportional to the quantity of paramagnetic gas present in the sample. Range: 0-3%, in three steps. Upper range may be as high as 0-10%. Accuracy: ± 2%. Remarks: Not affected by hydrogen or other common components of carrier gas.

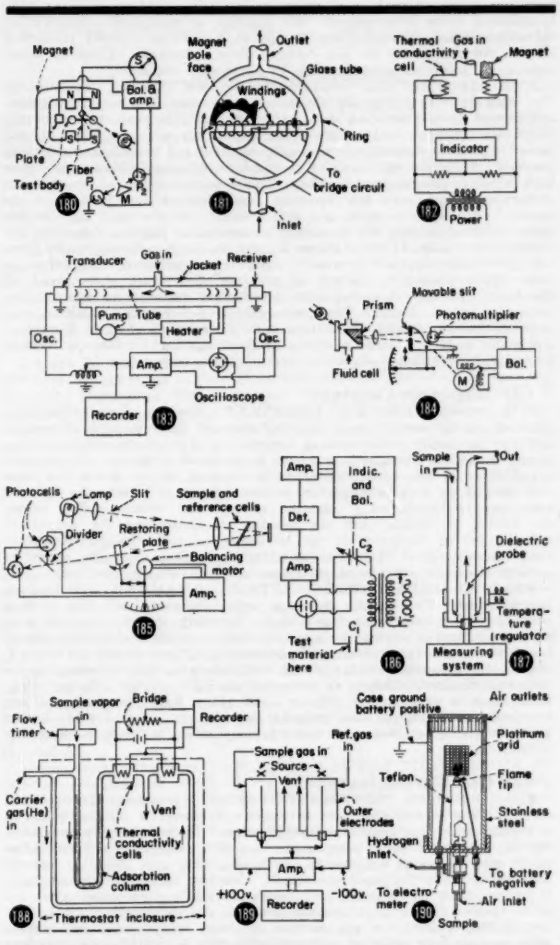


FIG. 182—MAGNETIC SUSCEPTIBILITY, THERMAL-CIRCULATION TYPE (Leeds & Northrup, others). Operates on same property as Fig. 180, but uses different principle. Two thermal-conductivity cells are connected into a wheatstone-bridge circuit and installed on sample line. Oxygen is received by diffusion. One cell is in a magnetic field; hence, oxygen is drawn up into it. Cell's resistance element heats the oxygen, thus reducing the gas' paramagnetic property and causing increased circulation with new oxygen entering the chamber. Difference in heat loss of two cells is a measure of oxygen concentration. Range: 0-5% oxygen or higher. Accuracy: ± 1.5% of full span, with maximum 0.15% oxygen. Remarks: Used specifically for analyzing gas mixtures for oxygen.

(b) Sonic Velocity

FIG. 183—SONIC GAS ANALYZER (National Instrument Laboratories). Acoustic waves travel at widely varying speeds in various gases. Merck design (shown) has a long water-jacketed tube through which gas flows both ways from the center, thus eliminating gas-velocity effect. An oscillator at one end generates sound waves, which are received by a crystal transducer at the other end. Phase of received wave is compared with that at sender. Phase shift is precise measure of sonic velocity. Range: Wide. Accuracy: Sensitive enough to detect 0.005% oxygen in air, or 0.00061% hydrogen. Remarks: Method gives rapid response, does not need removal of gas from pipeline for analysis. May be especially useful for corrosive or radioactive gases. Requires accurate

control of gas temperature. Nonselective, so is probably limited to binary or pseudo-binary mixtures.

(c) Index of Refraction

FIG. 184—AUTOMATIC REFRACTOMETER (Precision Scientific Co.). Index of refraction is a unique property of pure materials, and under favorable circumstances may be used for analysis (especially in two-component mixtures). Monochromatic light enters sample cell along face of prism, is refracted through prism on a path that depends on sample's refractive index. A slit is interposed in front of photomultiplier tube and driven to position of emergent beam by a balancing motor that is operated from tube output. Slit position is multiplied, recorded as refractive index. Range: Clear liquids of 1.32529 to 1.54409 refractive index. Accuracy: 3-4 in last decimal place. Remarks: Used on clear liquids. A recording unit, but can be adapted to control.

FIG. 185—PROCESS REFRACTOMETER (Barnes Engineering Co., others). Where Fig. 184 showed a single-beam refractometer, several commercial types (including Fig. 185) use a double beam to enable the instrument to be nulled. Light from a mercury arc is collimated and passed through a differential-prism cell, reflected and passed again through the cell. Half the cell contains a standard reference liquid; the other half, flowing process stream. Any change in refraction of the process stream compared with the standard liquid causes the light beam to deviate. The beam is split, and half goes to one photocell, half to the other. With equal-composition sample and standard liquids, both cells are illuminated equally. If compositions are not the same, a signal results from the electrically opposed photocells. Signal is amplified and drives a servo motor to restore balance by turning a restoring plate ahead of the beam splitter. Restoring-plate position is reported as comparative refractive index. Range: Transparent liquids. Accuracy: Limiting sensitivities down to 0.0001, 0.00001 or 0.000002 refractive index. Remarks: Applicable to binary liquid mixtures or those approaching binary. Widely useful with organics, inorganics. Gives instant response.

(d) Dielectric Constant

FIG. 186—DIELECTRIC CONSTANT (Foxboro Co.). Dielectric constant can be used in some cases to measure water content of liquids, and may be useful in determining composition of mixtures not containing water. Dielectric constant is a unique property of materials. For liquids, a condenser of two concentric tubes is installed in the liquid flow line and hooked to a high-frequency bridge circuit in which the balance condenser is automatically adjusted to null the detector. For solids, the hookup is similar, but the problem of controlling the weight of material in the condenser is not as simple as with liquids. Remarks: Unit monitors polar molecules in nonpolar liquids, especially water in various chemicals. Temperature compensation is usually necessary.

FIG. 187—DIELECTRIC-CONSTANT CHAMBER (Hallikainen Instruments). The sketch shows a probe chamber built like a heat exchanger to recover outgoing heat in incoming stream. Careful temperature control is attained by a temperature regulator and electric heater. Liquid flows through dielectric-cell portion in bottom, where a 7-mc. r.f. current (in a capacitor-bridge circuit with balancing motor) measures the dielectric constant. Output is converted to 3-15 psi. air. Range: Full-scale range is greater than 1%, or 1,000 ppm. Remarks: Unit analyzes for polar molecules in most nonpolar liquids, e.g., methyl ethyl ketone in toluene-benzene; water in acetone; isopentane in pentane, water in phenol, etc.

(e) Gas Chromatography

FIG. 188—GAS CHROMATOGRAPHY (Beckman Instruments, others). Watts-Carbide design is shown. Formerly a lab method, this is rapidly going into plant-stream applications. Method depends on absorption of a stream's vapor components in a chromatographic column, after which they are swept out one by one by a carrier gas. Finally, separate analysis is made for each component. Method is semicontinuous only, requiring 5 to 30 minutes per sample, depending on complexity and other factors. Plant units operate automatically, however. In Fig. 188, a controlled quantity of gas mixture is swept into the column (packed with an absorbent solid or an inert solid that is coated with absorbent liquid) by means of a carrier gas, usually helium. Sample flow ceases, but carrier flow continues, sweeping out the least firmly held component and then—in turn—the others more strongly held. Sample-carrier flow passes through one cell of a thermal conductivity bridge, while the pure carrier (acting as reference) passes through the other cell. Range: Lower limits as low as a few ppb. Accuracy: Precision is ½ to 2% of full scale. Remarks: Both laboratory and plant models are available for analysis of many gases and low-boiling liquids in petroleum refining, natural gas production, LPG, plastics, refrigerants, other chemicals. Separates close-boiling materials, can handle light and even rare gases. Up to eight components can be separated and measured, each of which shows up as an identifiable peak on the chart-recording bridge output. Ionization-type detectors have extended the range to levels of parts per billion (hydrogen-flame detectors, Fig. 190; and argon-ionization detectors, Barber-Colman). Liquid sampling valves and instruments that employ temperatures to 1,800 F. permit the analysis of high-boiling compounds. Shorter analysis time and more reliable equipment has permitted application of the process instrument to process control.

(f) Radiological Methods

FIG. 189—RADIOLOGICAL GAS ANALYZER (Hallikainen Instruments). Gas composition within an ionization chamber is used for measuring nuclear radiations. Composition has a marked effect on the ion current. Hence, this unit can be used for analyzing certain binary or pseudo-binary gas mixtures. For example, method will determine the argon in ammonia-plant circulating gases, after removing ammonia and hydrogen. Different gases give widely varying ion currents, but mixtures must be calibrated. Results are unpredictable. Instrument uses two temperature-controlled ionization chambers: sample passes through one, while the other contains a reference gas such as nitrogen. An Sr-90 source in each cell ionizes the gas, giving a characteristic current in each case. Currents are amplified and recorded as percent of the constituent measured. Accuracy: ±1% absolute, on 0-5% argon. Remarks: Has been used for both argon and ammonia. Is claimed to be both sensitive and accurate, although nonspecific.

BETA-RAY HYDROGEN METER (Hallikainen Instruments). Instrument is similar in construction to that of Fig. 189, except that a liquid-sample cell is built into one end of the ionization chamber between Sr-90 beta source and the chamber proper. Chemically bonded hydrogen in organic liquids has strong absorption for beta particles. However, betas are also used for thickness and density measurements (Section 8 and 9); so, for measuring hydrogen, density must be constant. Two cells are temperature-controlled, one containing reference liquid, the other the sample. Difference in the currrents set up in the cells depends on relative beta absorption, and can be recorded in terms of hydrogen content of sample. Accuracy: ±0.1% absolute. Remarks: Can determine % hydrogen in hydrocarbon and other organic liquids (if small corrections are applied for oxygen, sulfur and other heavier elements). If composition is constant, unit can be used to determine density within ±0.0002 grams per ml. A similar instrument (Central Scientific Co.) has built-in density balance.

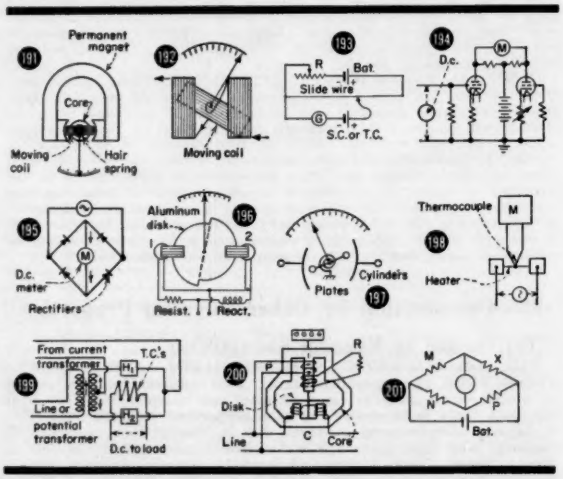
(g) Other Methods

FIG. 190—IONIZATION DETECTOR (Barber-Colman Co., Beckman Instruments, Inc.). In the hydrogen-flame ionization detector, column effluent is mixed with hydrogen and burned in the presence of air. If organic component is present, ionization results in the combustion gases, producing an electric field between a platinum grid and a burner tip. Any ions present in this field produce a current, which is detected and amplified by the electrometer. Range: 0-3 ppm. carbon. Remarks: Used in conjunction with gas chromatographic columns, but also—independently—to analyze for trace amounts of hydrocarbons in gas streams. Insensitive to water.

GASEOUS CONDUCTION (General Electric). A potential difference is applied to a heated cylinder that encases a central wire electrode. Variable-current flow results, strength of which depends on conductivity of contained gas. Remarks: Basis of General Electric's organic-halide leak detector.

BTU.-UNITS METER (Bristol Co.) is a device that measures Btu.'s by combining the flow rate through a process with the amount of heat released or absorbed. Can be used not only for controlling heat input or output but also for inferring the composition or rate of progress of a reaction. Heat rise or fall across the process is measured with series resistance-thermometers. Flow rate is measured and converted to position of a contact in a self-balancing bridge that measures delta-T. Recorder measures product of flow × delta-T, or the rate at which heat is released or absorbed. Remarks: Semiworks and plant reaction control. Instrument can be arranged to integrate Btu. input or output.

BOILING-POINT AND MELTING-POINT UNIT. Used as fundamental method in determining purity of single components. Range: Wide application. Accuracy: Can be very precise. Remarks: Chiefly a laboratory method.



23—Electrical Quantities

GENERAL: This section deals mainly with those electrical instruments that are used as parts of, or in connection with, process instruments. It makes no attempt to cover electrical instruments exhaustively. In understanding the individual instruments, it should be noted that in most cases they actually measure current, regardless of the quantity in which the dial is calibrated. Most voltmeters are therefore similar to certain ammeters, except for being of higher resistance and connected across the line, rather than in the line.

(a) D. C. Voltage

FIG. 191—PERMANENT-MAGNET, MOVING-COIL VOLTMETER (OR AMMETER). So-called D'Arsonval type, used for d.c., has a light coil connected across potential to be measured, within field of a permanent magnet. When current flows, reaction of field produced by coil with field of magnet causes rotation against a calibrated spring. Used for ranges from very low to very high. Galvanometers are instruments of this type.

FIG. 192—ELECTRODYNAMIC VOLTMETER. Has two stationary coils and a moving coil, all in series. Reaction of the fields of stationary and moving coils on current flow causes rotation vs. a calibrated spring. Not much used.

FIG. 193—BALANCE AGAINST A KNOWN POTENTIAL. This method, the null potentiometer, is one of the most used electrical measuring methods of process instrumentation. In its simplest form, as in the sketch, a potentiometer consists of two circuits containing sources of potential that have a common branch. When the position of the sliding contact on the slide wire is set for no current flow through the galvanometer, the voltage drops from the two sources are equal. To standardize the battery in the upper circuit, a standard cell is inserted in the lower branch and R is adjusted to give zero current flow when the slider is at some standard position. Then when an unknown voltage such as that from a thermocouple is substituted for the standard cell, the null position of slider on slide wire will show whether the unknown is greater or less than that of the standard. Furthermore, the slide wire can be calibrated to show how much greater or less.

FIG. 194—VACUUM TUBE VOLTMETER. Used where a high-resistance voltmeter is needed. Circuit shown in figure uses two three-element tubes, is good for ranges from 1 to about 1,200 v.

(b) A. C. Voltage and Frequency

FIG. 195—RECTIFIER BRIDGE. Enables a d.c. voltmeter to be used for a.c. by connecting four dry-type rectifiers in a bridge so that, whichever way the instantaneous current is flowing in the line, it always flows in the same direction through the meter. The arrangement is a so-called fullwave rectifier.

FIG. 196—FREQUENCY METER. Left half of off-center aluminum disk is acted on by induction voltmeter element 1 in series with resistance, gives constant torque at all frequencies. Right half acted on by element 2 in series with a reactance. It has opposite torque but is affected by frequency that, when increased, reduces current so disk turns to right to balance.

ELECTRODYNAMIC VOLTMETER. (See again Fig. 192). Is more useful as an a.c. voltmeter than for d.c., since torque remains in same direction regardless of direction of current flow.

FIG. 197—ELECTROSTATIC VOLTMETER. Draws almost no current. No connection is made to the moving element. With line across the outer plates, light cylinders on the moving element are oppositely charged at any instant and thereby attracted. Charges change polarity as the current reverses so that torque remains in same direction. Can be used for extremely high voltage, either d.c. or a.c.

ELECTROMAGNETIC MOVING-IRON VOLTMETER. This principle is used in most a.c. voltmeters and ammeters for power frequencies. Made in several forms, its simplest type is a soft iron core which is "sucked" into a coil carrying a current due to the field produced by the coil. Polarity induced in the iron reverses at each alternation so that alternating current can be measured.

(c) Current

GENERAL: As noted above, current measurement devices are in general similar to voltmeters and so will not be detailed further, except for one unique type.

FIG. 198—THERMOCOUPLE AMMETER. This device makes use of a heater through which the current flows. Heat produced is independent of whether the current is direct or alternating, high or low frequency. This heat is measured by a thermocouple which produces a voltage proportional to the current (heat) and is measured by an ordinary d.c. millivoltmeter or potentiometer.

(d) Power and Energy

Power measurement, DYNAMOMETER-TYPE METER. Power in watts is commonly measured by an instrument similar to the electrodynamic voltmeter (Fig. 194) in which, however, the stationary field coils are in series with the load, and the moving armature coil is shunted across the line. Hence, one measures current; the other, potential; and the combination, watts. POWER FACTOR in single phase circuits can be measured by a cross-coil electrodynamic or polarized-vane indicator. Polarized-vane indicator tied directly to line for 3-wire, 3-phase systems.

FIG. 199—POWER BY THERMAL CONVERTER. This device resembles the thermocouple ammeter but its output is proportional to power consumed by a load and can be telemetered for long distances. Potential leads, connected across the line, are connected to the primary of a transformer. Leads from a current transformer are connected into a bridge circuit so that current in one side of the bridge is added to by current induced in the transformer, while current in the other side is opposed by transformer current. Hence, the heat from heaters H_1 and H_2 will be different, depending on the load; and their average, determined by the series thermocouples, will be proportional to the load.

FIG. 200—INDUCTION WATT-HOUR METER. Commonest type of a.c. device for integrating watt consumption over a period of time, this meter consists of a potential winding *P* on an iron core, with current windings *C*. The armature is an aluminum disk with shaft behind the core. Interaction of flux produced by the three poles with the induced eddy currents in the disk causes rotation proportional to power. Adjustment of phase relations is obtained with a compensating winding and external resistance *R*. Revolutions counted by the register represent watt-hours.

(e) Resistance

FIG. 201—WHEATSTONE BRIDGE. One of the commonest circuits used in process instrumentation. Its purpose is to determine an unknown resistance such as that of a resistance thermometer in terms of three resistances. Known resistances *M*, *N* and *P* are connected, together with the unknown *X*, in a network as shown, with a galvanometer across one diagonal and a source of d.c. (or a.c.) across the other. *M* and *N* are commonly equal but, in any event, $X = P \times M/N$ so that, if a known value for *P* can be chosen that will show no current flow through the galvanometer, then *X* can be calculated. Commonly, such a circuit is used with some system for adjusting *P* automatically and continuously to give a null galvanometer deflection.

24—Measuring Methods

GENERAL: This section deals with the measuring devices that are used to convert the output of electrical industrial instruments into forms that can be used to operate a recorder, indicator or controller. It deals with measurements of potentials, resistances, capacitances or inductances. Such measurement methods are used with resistance thermometers, thermocouples, thermal conductivity cells, electrical conductivity cells, pH and redox cells; with strain gages and many position-measuring transmitting devices; and with a vast number of other types of instruments.

Most such electrical measurements are made by bridge circuits of one sort or another. These include wheatstone bridges, inductance and capacitance bridges, potentiometers and variations thereof. Some operate on d.c., some on a.c., and some may operate on either. Some use both—for example, measure the d.c. of a thermocouple, but convert the unbalance of the circuit into a.c. for amplification and operation of the balancing devices. A.C. bridges of various kinds have become more common in recent years.

Bridges of various sorts can in general be operated in two different ways; as deflection, or as null (balanced) circuits. Deflection bridges are relatively uncommon. The advantages of the null system in which the electrical values of the bridge are brought to a balanced condition, so that no current flows through the detecting device, are great enough in most cases to outweigh the greater cost of bridges with balancing features. Most balanced bridge circuits used in industrial instruments are of the automatic self-balancing type, although manual balancing is common in laboratory instruments, and in some industrial types such as electric conductive meters.

(a) Circuits

Direct voltage measurement by MILLIVOLTMETER. To a considerable extent, millivoltmeters are used in measurement of temperature by thermocouples. Many of these instruments are indicators, but recorders are also made, some in which millivoltmeter movement operates pen directly by aid of a chopper bar and others in which recording mechanism follows millivoltmeter pointer without contact by means of an oscillating coil pickup system. In this method, pointer carries aluminum vane, which moves between oscillator coils on a movable arm. If pointer attempts to move out of field of coils, output of an oscillating circuit is changed to drive a motor that causes coil carrying arm to move in same direction and at same speed as pointer. Position of arm controls recorder pen at corresponding position. Arm position can also operate control contacts easily, since plenty of power is available.

Voltage measurement by DEFLECTION POTENTIOMETER. In elementary potentiometer circuit of Fig. 193, it was noted that, with battery adjusted vs. standard cell, unknown voltages could be read by position of slider on slide wire, which would give zero deflection of galvanometer. If slide wire is replaced by a series of tapped resistances, and galvanometer is calibrated as a millivoltmeter, then movable contact in unknown voltage circuit can be set at a point which will give only a little deflection to instrument. If both taps and millivoltmeter are calibrated in temperature (assuming a thermocouple is being measured), then temperature is read as sum of that indicated by tap, and that indicated by millivoltmeter. Method is sometimes used where a low-cost indicator for one or a number of temperatures is desired and manual operation is suitable.

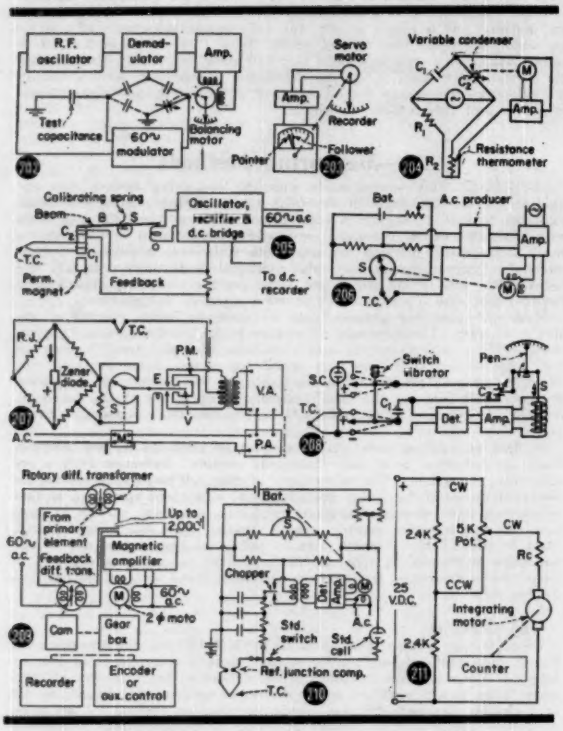
Voltage measurement by NULL-BALANCE POTENTIOMETER. (See Fig. 193.) Most instruments requiring potential measurement use a null-type self-balancing circuit similar to Fig. 193. Null balance has advantage that, since no current is drawn in balanced condition, measurement is unaffected by resistance of unknown voltage circuit, or by changes in resistance. Long leads are no disadvantage. In Fig. 193, a switch (often operated automatically in self-balancing instruments) is provided for switching standard cell into circuit for standardizing battery by means of resistance *R*. Three resistances in circuit are ordinarily of manganin for low temperature coefficient of resistance, and fourth resistance is of nickel for cold-junction compensation. [See Section 1(d) for method of bringing cold junction to instrument by compensating leads.] With thermocouple in circuit, instrument is balanced (manually or automatically—see below) by moving slide wire contact until current through galvanometer *G* is zero. For this case, slide wire may be calibrated to read temperature directly.

FIG. 202—CAPACITANCE BRIDGE (Robertshaw, A.&I. Div.). Used mainly for capacitance level measurements. Probe in tank serves as one capacity in a four-capacity a.c. bridge. Second plate is tank wall. Variation in capacitance unbalances bridge, producing a 60-cycle modulated r.f. output that adds to signal from oscillator, is demodulated and amplified to drive balancing motor in direction to re-balance bridge by changing variable capacitor. Motor also positions recorder.

FIG. 203—CAPACITY FOLLOWER (Robertshaw, A.&I. Div.). For recording or controlling from millivoltmeters or other low-torque units, vane on pointer is followed without contact by a servo-operated follower. Capacitance bridge circuit similar to Fig. 202 detects capacitance between vanes, drives follower and recorder to maintain constant capacitance.

CAPACITANCE POTENTIOMETER (Foxboro Co.). (See Fig. 208.)

Capacities can be substituted for a pair of resistances in a potentiometer-type circuit, (see below).



RESISTANCE BRIDGE. (See Figs. 8, 201.) Widely used with resistance thermometers, conductivity meters, thermal conductivity gas analysis, etc. Applications where variations in lead resistance could upset response from sensitive element resistance use a three-wire lead as in Fig. 8. Lead wire resistance changes are put into both sides of bridge and so nearly cancel out. Variations of this circuit are sometimes used, such as a double-slide-wire type that further improves canceling out of lead wire resistance changes. As in potentiometers, wheatstone bridges used in industrial instruments are commonly automatically self-balanced with some form of detecting mechanism G that will move slide wire contact S to point of zero current flow through G. Such bridges may use d.c. or a.c.

INDUCTANCE BRIDGE. (See Figs. 222, 224.) Either two or four of the resistances in an a.c. wheatstone bridge can be replaced by inductances (or impedances). Fig. 222 shows a type that is self-balancing without usual self-balancing mechanism. Fig. 224 is a type used for precision determination of position of an instrument element.

FIG. 204—CAPACITANCE BRIDGE (Foxboro Co.). As noted above for potentiometers, two capacitances can be substituted for resistances in a wheatstone bridge circuit. Shown used with a resistance thermometer, capacities C_1 and C_2 replace a pair of resistances in Fig. 8. In a.c. bridge, any unbalance is amplified electronically and fed to reversible motor for altering the value of C_2 until current flow through detector circuit ceases. Temperature R_2 is indicated by position of balancing condenser.

(b) Balancing Methods

FIG. 205—MICROSEN SYSTEM (Robertshaw, A.&I. Div.). This is an electronic-mechanical balancing system in which an electrical or mechanical input (measurement) is balanced against an accurately proportional d.c. output to an indicating or recording instrument. Basis of several variations of system is a balance beam that is upset by the primary measurement so as to affect an oscillating electronic circuit. Balance is restored to beam as circuit output reaches a value equivalent to initial upsetting force. Applied to measurement of a thermocouple potential, system consists of beam B (Fig. 205) with calibrating spring S and an armature at one end carrying coils C_1 and C_2. At other end, beam is in field of an oscillating coil O in an electronic oscillating circuit. Voltage output of thermocouple TC applied to coil C_1 causes rotation of B toward permanent magnet. But this changes electronic circuit output to recorder, also changing feedback through C_2 to restore balance. Instead, C_2 and electrical feedback may be omitted and direct mechanical feedback from recorder may be used to re-balance beam. Note that in this application system acts as a d.c. amplifier. Beam is comparable to a millivoltmeter in that circuit is not "nulled," and lead resistance has to be considered. Can operate up to 1,250 ft. from TC. On temperature, accuracy claim ½% of scale. Other applications: pressure, strain gages, pH and conductivity.

FIG. 206—DYNAMASTER (Bristol Co.). Thermocouple output is applied to potentiometer. If not in balance, current in TC circuit is converted to a.c. by a synchronous switch. A.C. output is amplified and applied to balance motor to drive S in proper direction for restoring balance. This system with modifications can be used to balance circuits where the electrical quantity can be represented by voltage, current, capacitance or resistance. In resistance thermometers, for example, an a.c. bridge is used. Unbalance output, being a.c., can be amplified directly.

FIG. 207—BROWN ELECTRONIK (Minneapolis-Honeywell). Thermocouple output applied to potentiometer circuit if unbalanced is converted to a.c., direction of unbalance determining phase relation between generated alternating current and a.c. supply voltage so as to determine direction of correction applied by balancing motor M. If slide wire S is not balanced, current flow in thermocouple circuit is converted to alternating by transformer through action of vibrating reed converter driven by a.c. at 60 cycles by coil E. Transformer output is amplified by voltage and power amplifiers and applied to balancing motor M. If in-phase, motor corrects for overbalance. If 180° out-of-phase, motor corrects for underbalance. The Zener diode circuit provides a constant and continuous standard voltage to the measuring circuit from line voltage. Reference junction resistor RJ compensates for variations in thermocouple reference-junction temperature.

STRANDUCER (Minneapolis-Honeywell). An electromechanical device that balances a d.c. millivolt input from a sensing unit against a known voltage. By using four resistance strain-gage elements to form the variable arms of a wheatstone bridge circuit, infinite resolution on impressed signal is obtained. Change in input drives the motor in one direction or the other, increasing tension on two of the wires, while decreasing it on the other two. Change in stress changes electrical resistance of the wires and continues to change it until bridge is electrically balanced.

FIG. 208—DYNALOG (Foxboro Co.). This system is unusual in that it operates direct from standard cell without a separate battery and so needs no standardization. Vibrated switch alternately connects thermocouple and standard cell SC into capacitor bridge (contacts in upper position), then shorts capacitors through detector (contacts in lower position). SC charges C_2, TC charges C_1. If charges are unequal, detector output is amplified to drive solenoid bridge S and reposition C_2 and recorder pen. When balance is reached, short-circuit discharges become equal. Current drawn from SC is small enough that usual battery is not needed. Variations of capacitor bridge are used for other variables expressed as resistance, capacitance or inductance. Claimed accuracy is ¼%.

Instead of a standard cell, some potentiometers use a regulated d.c. source, e.g., Bailey Meter's d.c. receiver for thermocouple and other d.c. pickups. This has a regulated electronic d.c. supply to serve as reference voltage without a standard cell, and no need for periodic standardization.

FIG. 209—ELECTROSYN SYSTEM. (American Standard). This method uses a magnetic amplifier, requires no vacuum tubes. Primary measurement rotates a rotary differential transformer connected to amplifier. A.C. voltage output is amplified, turns two-phase motor geared to recorder, other auxiliaries such as encoders for telemetering or data logging and, through cam, turns a second differential transformer, which feeds back an opposing a.c. voltage. Motor position, which just balances feedback voltage against primary voltage, represents current value of variable. Any change in primary measurement is followed by immediate rebalancing. Primary element and amplifier-recorder can be up to 2,000 ft. apart. System shown is used for mechanical inputs such as pressure and differential pressure. Temperature input from resistance thermometer is handled similarly except that a variable resistor is used for feedback balancing.

NONGALVANOMETER BALANCING SYSTEMS. Most makers of self-balancing bridge and potentiometer instruments now supply continuous-balance instruments in which galvanometer formerly used is replaced by some method of electronic detection of unbalance. Characteristically, such instruments balance so rapidly as to be able to carry pen across entire chart scale in 2 to 20 sec.

FIG. 210—SPEEDOMAX (Leeds & Northrup). Thermocouple output is applied to potentiometer circuit. If unbalanced, the excess is chopped to a 60-cycle a.c., amplified and used as power supply for one phase of a two-phase motor; other phase is powered by plant supply. Motor drives a balancing slidewire in proper direction to rebalance thermocouple output. At balance, supply of amplified current ceases. Similar balancing system is used for other bridge circuits.

(c) Monitoring and Data Logging

GENERAL: Monitoring is the automatic supervision of one or more process variables. It generally implies use of alarms to show when variable is above or below set point by more than a predetermined tolerance. May also include, in addition to alarm function, digital logging of these variables at intervals by printing out numbers.

Continuous monitoring means a constant watch over all affected variables. Scan monitoring means sequential switching of instantaneous values of the variables and their comparison with standard values, with sounding or showing of alarm if out of limits and possible printing of digital value of variable—sometimes in color or on special typewriter for trend recording.

In simplest form, monitoring generally is continuous and uses high-low alarm contacts in each variable's own measuring instrument. In systems of more than a few points, scanning is likely to be used so that some equipment can be time-shared among all variables. This means using sampled data, requiring that each point be sampled often enough to catch important changes.

DATA LOGGING. Scanning system, in addition to alarm function, may convert analog information acquired from each primary measuring system into digital information for automatic print-out on electric typewriters, for telemetering (i.e., Teletype code), or for feed to digital computers. Details are beyond scope of this review.

FIG. 211—ELECTRICAL INTEGRATOR (GPE Controls, Inc., others). Any linear quantity that can be represented by a d.c. voltage or current signal can be automatically integrated by this device. Input signal

drives high torque motor whose speed is proportional to the applied voltage. Motor shaft drives counter through gear train. Integration is continuous and has accuracy of ±½%.

MAGNETIC TAPE RECORDERS (Bendix Corp., others) can log independent and dependent variables such as stress-strain relations during actual test operations. Later, data stored on tape can be analyzed by computer or converted to printed form via typewriter.

TRANSDUCERS are primary measuring devices capable of producing an electrical signal such as a voltage, current, frequency or pulse rate. These include thermocouples, resistance thermometers, some velocity-type flow meters. If primary measurement results in an instrument position (e.g., pressure gages, head-type flow meters) position must be converted to an electrical quantity with a secondary transducer.

Individual electrical outputs are individually corrected for scale range and, if necessary, linearized to make response linear with variable. Certain measurements must then be operated on mathematically to convert to kind of quantity to be recorded. For instance, flow measured in differential pressure must be square-rooted. If total flow is to be recorded, flow rate must be integrated. A programmer then selects the channel to be recorded and feeds it to scanner where value is compared with a standard, e.g., a reference voltage, for that point. If outside limits are set, alarm system will be activated. Otherwise, quantity is fed to digital converter for normal recording.

In some systems an alarm will initiate operation of separate trend recorder for more frequent read-out. Or operator may plug in graphical recorder for continuous measurement of that variable.

DIGITAL CONVERTERS are of many types, both electronic and mechanical. In mechanical type (e.g., Fischer & Porter) shaft position of the self-balancing scanner potentiometer, time-shared by all variables, rotates a geared series of "units," "tens" and "hundreds" drums carrying "plateaus" and "valleys." These produce a pattern of two-way switch setups, which in various combinations can code any quantity (represented as shaft position) in terms of numbers from 1 to 1,000, in any code such as decimal, binary, for typing, telemetering or card punching.

VAPOR PRESSURE RECORDER (Hallikainen, Precision Scientific). Vapor pressure of continuously-sampled gasolines or liquefied petroleum gases is analyzed and recorded. The Hallikainen device (Shell Dev. Co. design) passes liquid sample into temperature-controlled vaporizer column where it reaches equilibrium with its saturated vapor phase. At this point, vapor pressure is measured by a Moore pressure transmitter (Fig. 218), which provides a pneumatic output signal. Precision Scientific device (Standard Oil Co., Ind., design) uses constant-temperature bath to preheat sample, which then passes into air-saturation chamber where sample is brought into equilibrium with air. Liquid and air-vapor mixture is then pumped through capillary vaporizing-coil at constant rate. Pressure transducer at downstream end of coil senses pressure and transmits signal to recorder.

BOILING POINT ANALYZER (Hallikainen). End point of distillate fraction is determined automatically by introducing sample into a falling-film flash evaporator where 97% of the sample is evaporated. The evaporator tube, which is closed and pointed at its lower end, contains a thermocouple to measure end point temperature. The residue of the sample flows drop-wise between an exciter lamp and a photosensitive detector to produce a signal proportional to the drop rate. This signal fed to a control circuit provides proportional and reset functions to control heat to the evaporator so as to maintain the drop-rate constant. An INITIAL BOILING POINT analyzer (Hallikainen) and FLASH POINT recorder (Precision Scientific) provide automatic analysis for these values.

25—Transmitters and Telemeters

GENERAL: The distinction between TRANSMITTERS and measuring devices is not always clear. A measuring device is one that converts a primary indication into a position (or into some form of energy that can easily be displayed as position) on a scale to show the value of the primary variable. Some transmitters do the same thing, though others are primarily relays. If there is a real distinction, it is that transmitters can display the value of the primary variable at a considerable distance from the primary element.

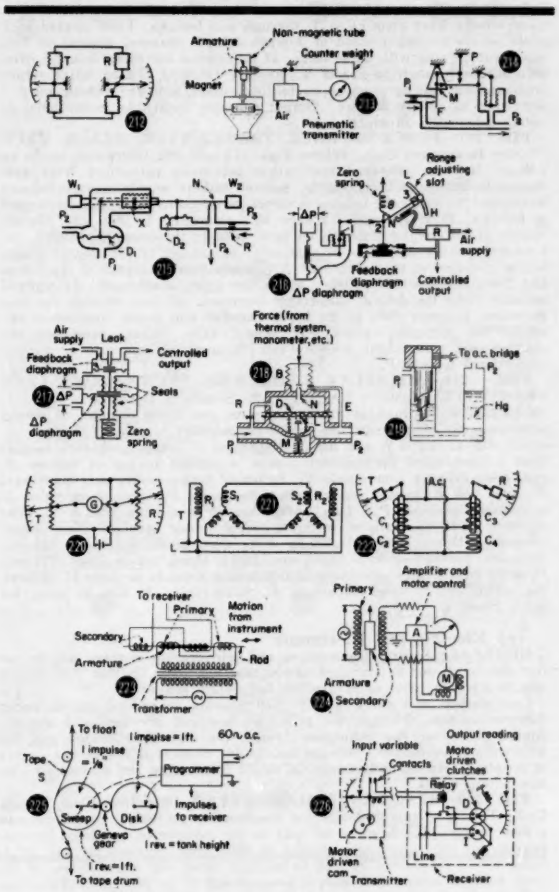
Transmitters for still-longer distances are called TELEMETERS. In some cases, telemeters are designed to transmit over their own wires; in other cases, over phone wires or by microwave. Transmitters, however, may be pneumatic as well as electrical; but being shorter-distance senders, they use their own communication connections between sending and receiving devices.

A great many different methods are used for extending the distance that measurements can be sent. In general, these include hydraulic, pneumatic, electrical and electronic. Short-distance methods of getting away from friction-producing elements such as stuffing boxes include mechanical (torque tubes) and magnetic devices.

(a) Hydraulic and Magnetic

FIG. 212—HYDRAULIC TRANSMISSION (Liquidometer Corp.). Method used for transmitting liquid-level measurements from a tank float employs two transmitting and two receiving bellows, connected by two lines, with system filled with liquid. Purpose of double-bellows system is to compensate for ambient temperature changes. Expansion or contraction, due to temperature, affects each bellows system equally, being cancelled out by link between receiving bellows. However, movement of pointer at transmitting end (representing position of float or other measurement to be transmitted) expands one bellows, contracts other, so moves receiving pointer an equal amount.

FIG. 213—MAGNETIC FOLLOWER. Method often used to transfer motion inside a sealed system to outside without loss of accuracy due to friction in a stuffing box. For example, used in level gages and controllers, flow manometers and rotameters. A level gage made by Magnetrol, Inc., uses magnetic follower to operate level control switches. Yarnall & Waring makes a level gage (Fig. 80) that transmits position of a manometer by means of a magnet that turns a spiral follower attached directly to the pointer. In Fig. 213, a float in a level gage or manometer operates armature in a nonmagnetic tube to position a transmitter.



(b) Pneumatic

GENERAL: Pneumatic transmitters are coming into extensive use, especially since development of the pneumatic force-balance type of measuring device. Such transmitters are used for temperature, pressure, differential pressure from flow, level and density measurements, weight, force and position. With the development of close-coupled control systems with remote set and indication at the panel board, they are being used to transmit to a controller close to point of measurement, and to an indicating or recording instrument at a remote panel board. Similar transmitters, balanced against pressure of a spring, are being used to produce loading pressure for remote setting of controllers in such installations. This method takes the recorder out of the control loop, puts controller and point of measurement close together, and hence cuts instrument lags to minimum.

FIG. 214—POSITIONING NONBALANCE TRANSMITTER. Diagram illustrates principle, shows no particular type. Measurement pointer P positions a flapper F before a nozzle, raising or lowering pressure P_2 by changing leak at nozzle. Bellows B moves movable fulcrum M in direction to oppose change, acts as a feedback so that each output pressure P_2 demands an exact position of F. Thus P_2 is proportional to position of pointer P. P_2 can be transmitted. For use over distances where a considerable lag in transmission is to be avoided, P_2 is fed to a relay air valve to increase flow during time that P_2 is changing.

FIG. 215—FORCE-BALANCE TRANSMITTER, BEAM TYPE (Republic Flow Meters Co., others). Force from any sort of measurement (shown here as that of a differential-pressure diaphragm) is applied to a weight-balanced beam pivoted at point X. In this application, X is inside a bellows used as a frictionless seal for the differential-pressure system. Beam obstructs flow of air from nozzle N, which is supplied with air at pressure P_3 through restriction R. Assuming P_1 increases, beam will tilt to raise nozzle pressure P_4, but this increases pressure on diaphragm D_2,

which restores beam to substantially its original position. Hence, P_4 is balanced vs. the differential pressure, either exactly or in some multiple, depending on the relative lever arms. P_4 is transmitted. A similar beam type can be used for ratioing, as in Fig. 251.

FIG. 216—FORCE-BALANCE TRANSMITTER, NULL-BALANCE-VECTOR TYPE (Republic Flow Meters Co.). Newer type than Fig. 215, in which vectorial forces are combined by linkages. Range is adjusted by changing angle theta by sliding pivot 3 in a calibrated slot. Differential pressure delta-P is measured by a diaphragm, with motion taken out by lever pivoting at 1, through seal bellows. Link pivoted at 2 raises or lowers link pivoted at 3 when delta-P changes, amount of this movement varying with angle theta. If differential increases, link 2-3 lifts, lowering air pressure in nozzle N. Reverse air relay R then raises output pressure, also raising pressure on feedback diaphragm and moving pivot 2 downward to restore balance. Output pressure is directly proportional to initial differential pressure.

FIG. 217—FORCE-BALANCE TRANSMITTER, STACK TYPE (Taylor Instrument Co.). Where Figs. 215 and 216 interposed beams or linkages between measured and output pressures, permitting lever arm change to change proportionality, several makers supply a force-balance instrument in which the balance is direct, on opposite sides of a diaphragm or bellows. Figs. 217 and 218 show this principle. In Fig. 217, the resultant of differential pressure on both sides of the lower diaphragm (or a single pressure on the lower side only) is opposed by the controlled air-output pressure so as to balance. Air supply enters through a restriction and flows through the chamber above the upper diaphragm. If upward pressure from the delta-P diaphragm increases, air loss through the leak decreases, pressure rises in the upper chamber and outlet, meanwhile balancing the increased delta-P. If delta-P falls, leakage increases, top chamber and transmitted pressure fall. Transmitted pressure is directly proportional to delta-P.

FIG. 218—AIR-RELAY FORCE-BALANCE STACK-TYPE TRANSMITTER (Moore Products Co.). Similar in principle to Fig. 217, except that it incorporates an air relay to give rapid changes in output pressure. Air at pressure P_1 enters transmitter, is applied through restriction R to nozzle N and top of diaphragm D. Any force such as that from a liquid-filled thermometer system is applied to top of bellows B, restricting delivery from nozzle N. Increased back-pressure over diaphragm D closes leak L through porous-center diaphragm D, opens main valve M to increase pressure P_2. This works through equalizing line E to raise pressure in B, thus almost restoring initial nozzle opening. Now output pressure balances force. Assuming force then decreases, nozzle delivery increases, pressure over D falls, and leak L bleeds air to lower P_2 until P_2 again equals force. Response of instrument depends on force of calibrating spring under main diaphragm D. Main valve M acts as relay for quick changes.

(c) Electric and Electronic

GENERAL: Several transmitting and telemetering methods are in use that can be classed as electrical rather than electronic, in that they do not require vacuum tubes or transistors for amplification.

One method now being widely used appears in several guises under different names, although the principles involved are generally similar. Among these are the inductance bridge, the impedance bridge and the differential transformer. All are a.c. bridge circuits in which the degree of coupling between inductances is varied by altering the amount of iron core within a coil.

FIG 219—RESISTANCE MANOMETER (Republic Flow Meters Co.). This is a unique device for transmitting the height of mercury in a flow manometer. A spiral of rods in the manometer, arranged to compensate for the square-root relation in flow (See Sections 2e and 5) is connected to resistances so that as mercury shorts out more or less of the rods, total remaining resistance is proportional to the flow rate. Flow rate indication and recording are obtained by passing a.c. from manometer through a bridge circuit that measures the conductance by means of a core that is drawn a certain distance into a coil, the distance depending on the resistance of the manometer. Integration of flow is by means of an instrument similar to a watt-hour meter.

FIG. 220—WHEATSTONE BRIDGE TRANSMITTER. Null-balance wheatstone bridge can be used to transmit indications by contact on slide wire T, positioned by the measurement to be transmitted. Unbalance indicated by galvanometer G then operates to move contact on slide wire R to balance position, which then reproduces position of T. Alternatively, transmitting resistance T in Fig. 220 may be varied by temperature (resistance thermometer) or by a force (strain gage), and the resistance change mirrored at R. For example, strain gages are used by Brooks to transmit rotameter readings.

FIG. 221—SELF-SYNCHRONOUS MOTORS. Motors with three-phase stators S_1 and S_2 and two-phase rotors are connected to same line. Rotors remain stationary unless turned by an external force. If primary rotor R_1 is turned, R_2 will follow closely with lag of 1 to 3°. Selsyns may be paired to transmit both feet and inches in remote level indication (Shand & Jurs). "Inches" transmitter turns one revolution for each foot. "Feet" transmitter turns one revolution for 60 ft. of range. Corresponding indications of two receiver selsyns permit readout in feet and inches.

FIG. 222—INDUCTANCE BRIDGE. Used for transmitting indications from inside sealed instruments, such as flowmeter manometers, rotameters, etc. Transmitter and receiver coils are connected as shown by three wires in a bridge arrangement and supplied with a.c. Transmitter soft-iron armature is positioned vertically by the measurement to be transmitted. Receiving armature positions itself similarly. This device is self-balancing without usual balancing devices. Any unbalance due to armatures being unequally placed in coil pairs results in current flow through center lead that brings about rebalance by altering flux distribution until balance is reached.

FIG. 223—DIFFERENTIAL TRANSFORMER (Automatic Timing & Controls, Inc., others). This device is an a.c. motion transducer that can be designed to produce an electrical output over a full range with any desired range of motion of the armature. Type shown allows long armature travel; other types are designed down to fractions of an inch. Transformers have one or two primaries and two secondaries, generally connected to "buck" each other. A.C. is applied to primary. A.C. produced in secondaries depends on position of armature and amount of coupling so produced. Such devices provide accuracies of ½ to 1% of full range and can be used to transmit forces, pressures, differential pressures, weights, and the like. Can transmit up to 5,000 ft. Type illustrated has linear motion of core. Rotary differential transformers are used in a number of instruments, e.g., Inertial Instrument Co.'s mass meter (Fig. 71) and Electrosyn transmitter (American Standard, Fig. 209). Several instruments use what is in effect a differential-transformer bridge, e.g., Electrosyn transmitter, and a remote level transmitter supplied by Yarnall-Waring Co.

FIG. 224—IMPEDANCE BRIDGE (Bailey Meter Co., others). Transformer with single primary, supplied with a.c., and double secondary has movable armature I positioned by measurement to be transmitted. Secondaries S_1 and S_2 are in a bridge circuit. Unbalance due to I not being centered is amplified by A and transmitted to a balancing motor M, which repositions slide wire to balance. Slide wire position is a measure of position of I in transformer.

D.C. CONVERTER (Bailey Meter Co.). Variation of Fig. 224 eliminates amplifier and slide wire, uses two diodes to convert output of secondaries to d.c. in a d.c. bridge. Unbalance resulting from armature movement is put out as d.c. voltage proportional to armature position.

D.C. TRANSMITTER (Robertshaw, A.&I. Div.). Microsen-balance measuring device of Fig. 205 is used to transmit measurements that are initially voltages or forces, converting these to d.c. that can be transmitted considerable distances. Receiver employs a second Microsen with feedback to make pointer position proportional to signal. Signal positions the rotary solenoid from output of receiving Microsen, with mechanical link from solenoid to balance-beam, thus restoring spring. Solenoid positions the indicating pointer. Mechanically loaded Microsen beam can be used for remote set-point adjustment of electronic controllers.

(d) Impulse and Timed Signal

GENERAL: Impulse and timed-signal methods of telemetering have advantage of giving accuracy independent of supply voltage variations. There are several methods: (1) sending a number of electrical impulses proportional to the value of the variable, and counting pulses at the receiving end; (2) sending a signal whose frequency is proportional to the variable; (3) sending a single pulse whose duration, as a fraction of a fixed time interval is the same as the ratio of the variable to its maximum value; and (4) sending a pattern of pulses in code, such as decimal or binary-decimal, corresponding to the digital value of the variable.

FIG. 225—PULSED-SIGNAL LEVEL TELEMETER (Shand & Jurs). One of several pulse methods of transmitting continuously varying variables such as liquid level and tank temperature is shown in Fig. 225. Transmitter cycle has three parts. Remote operator signals any individual tank for level and/or temperature. Selected transmitter first sends pulse group identifying itself. Then sends level, first "feet," then "inches" by eighths. "Inches" disk is driven by perforated steel-float tape, makes one revolution for each foot of float movement. Then advances "feet" disk one increment through Geneva gear. When instrument is asked to transmit, a motor-operated sweep scans each disk for its position, first the "feet" and then the "inches" disk, sending for each a number of pulses corresponding to the disk position. Receiver dials are ratchet-operated by incoming pulses to count exactly.

FIG. 226—TIMED-SIGNAL TELEMETER (B-I-F Industries). Rotating cam lifts a follower for a period during each cycle proportional to measured value. This closes switch and sends a signal over a two-wire line to receiver. Duration of signal during each cycle is therefore proportional to measured variable. Receiver has two clutches, one "increase," one "decrease." The first runs while current is on, the second during part of cycle when current is off. Transmitted value is the difference. Pen moves only when difference changes. Works over long distances at high accuracy.

FREQUENCY-CODE DATA TRANSMISSION (Bendix Corp.). Physical variables of a process are sensed by instruments compatible with the Bendix Electro-span system to produce an electrical signal that may represent contact closures or openings; or voltage or current. In the Electro-span system, three different elements are used to convert the basic sensor outputs into digital form. Transmission is by means of a series of five binary-bit characters over teletype or telephone lines for remote locations or by direct wire for nearby sites. If telephone line is used, data is transmitted by a polytonic method of transmission. Transmission of a single five-binary-bit character is performed by simultaneous transmission of five tone-signals on the communication line, where the absence or presence of a single tone distinguishes between a binary "1" or "0".

26—Controllers

GENERAL: Controllers are of many types, although most of them can be classified according to the type of control that they are able to supply. Apart from the control type, there are two general methods of controller operation; self-operating and pilot-operating. SELF-OPERATING CONTROLLERS use energy taken either directly or indirectly from the controlled system to operate a valve or other controlled device that regulates the supply of the control medium. PILOT-OPERATED CONTROLLERS control a supply of energy in the form of a fluid under pressure (usually air), or electricity. The controlled pilot fluid then makes the necessary adjustments to the controlled device. An intermediate type of controller uses the energy of the control medium to amplify its responses and so control the control medium.

MODES OF CONTROL. Most industrial control problems involve as the end result of the control action the regulation of flow of a control medium such as steam or other heating medium, or electricity, or a process fluid. This means control of flow. The flow can be controlled in an off-and-on manner—either between high and low limits or completely off and on; or it can be controlled in a throttling manner—at a rate intended to balance the instantaneous demand. Since the throttling type of control seeks to proportion the flow of control medium to the demand, it is known as proportioning or proportional.

PROPORTIONAL CONTROL is the type most used in industrial work, but for processes other than the simplest, additional control responses beyond simple proportional action are often added. The first of these is the reset response. In any simple proportional controller, there is only one rate of demand at which the controller will control exactly at the desired control point. If there are large or permanent changes in demand, the controller must be reset by hand. To avoid this, many controllers have the reset feature supplied automatically. A comparison of Figs. 241 and 242 shows one way in which this can be accomplished. In a proportional controller without reset, the controller output (e.g., pressure on the control valve) is related directly to values of the measured variable. This means that with load changes, different controller outputs will be needed to maintain the same control point. Automatic RESET TYPE supplies this flexible feature by adding a second controller response, which changes the controller output at a rate proportional to the amount of deviation.

There are still other possible responses that can be added to a proportional controller. The most common one, in addition to reset, is called the DERIVATIVE-RESPONSE TYPE. It changes controller output at a rate in proportion to the rate of change of the deviation. Its effect is to give the process an extra control when a sudden increase in demand takes place, then to cease its effect entirely as soon as the deviation has been arrested. One way to add this response is shown in Fig. 243.

(a) Self-Operated

FIG. 227—SELF-OPERATED PRESSURE REGULATOR. This controller adjusts its valve opening by the relation between the downstream pressure applied to bottom of diaphragm D and the pressure of a spring S. If downstream pressure falls, valve opens wider; while if the pressure rises, valve closes. Self-operating temperature regulators are similar. Pressure of a filled (usually vapor pressure) thermometer system is applied to a bellows that opens or closes the valve. If temperature rises, valve closes to decrease flow of heating medium (or valve opens to increase the flow of cooling medium). Since some margin for operation is required, these devices cannot give as close control as pilot-operated controllers. They are used for less-critical control problems such as water heating, dry rooms, jacket water cooling, etc.

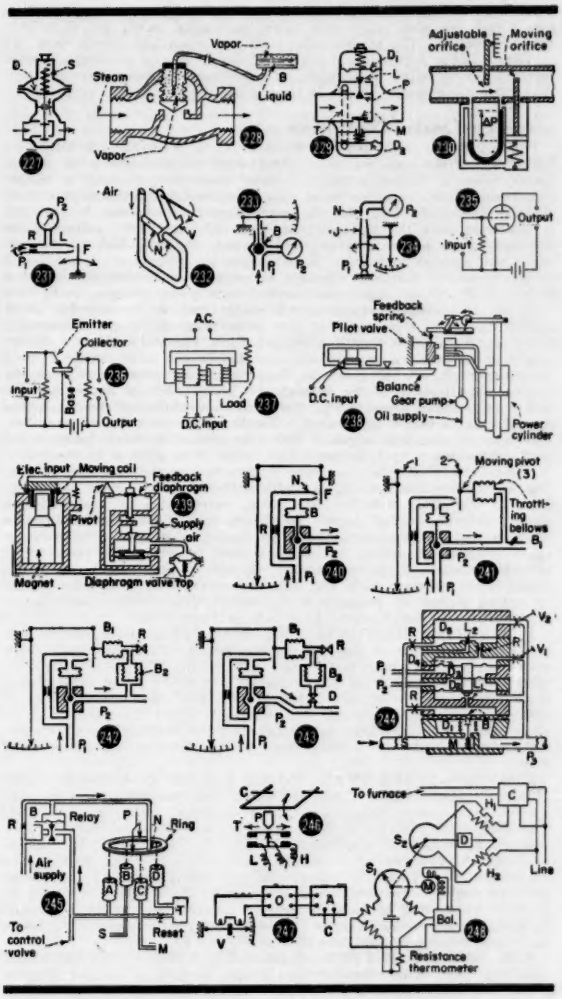
FIG. 228—HOT-CHAMBER REGULATOR (Fulton Sylphon). This device represents the class of intermediate controllers in which energy from the control medium is used to increase sensitivity of control. Hot chamber C within the steam valve (on supply side) receives vaporizing liquid from temperature bulb B if controlled temperature rises. This liquid vaporizes in C, provides energy to close the valve against steam flow. Decrease in temperature at B allows vapor to condense, drawing vapor back from C and increasing valve opening in response to demand.

FIG. 229—SELF-PILOT PRESSURE REGULATOR. Except for small sizes, pressure-regulating valves usually have a built-in pilot device operating from the pressure of the fluid being regulated. Valve in Fig. 229 is typical. Where self-operating type (Fig. 227) gains control only from downstream side, self-piloted types use fluid that is bled from high-pressure to low-pressure side to act as a source of pilot energy. If downstream pressure fails, diaphragm D_1 opens pilot valve P, allowing upstream pressure to force D_2 upward and increase opening of main valve M. When upstream pressure rises, D_1 closes P, opens L to low-pressure side and allows D_2 to fall and M opening to decrease.

FIG. 230—SELF-OPERATING FLOW REGULATOR (W. A. Kates Co.). Constant pressure drop is maintained across adjustable and moving orifices. Adjustable orifice is set manually to desired flow rate. In the device, a compensating sleeve valve, located in the inlet flow, is connected to the moving orifice between the intermediate and outlet chambers. Pressure difference between chambers oprates moving orifice. Loading weight attached to sleeve determines the net pressure difference. Increase in inlet pressure causes rise in intermediate pressure. Sleeve and disk move upward, thus restricting inlet ports until intermediate pressure returns to original value above outlet pressure. Increase in back pressure causes reverse action to take place. Pressure differential within unit adjusts valve position proportional to desired flow.

(b) Pilots and Relays

FIGS. 231, 232, 233, 234—NONRELAY PILOTS. Pneumatic and hydraulic controls use various forms of pilot device to produce an output pressure that varies in some suitable manner with a primary measurement. Most of them also incorporate a relay to increase flow of pilot medium while changes are taking place. For simplicity, relays are omitted in these figures. Fig. 231 represents the common flapper or baffle type in which the measurement is translated into position of the flapper in front of the nozzle. If the flapper approaches, pressure of air P_2 rises, leakage at L decreases. The free-vane flapper, Fig. 232 (Bristol), was developed to overcome the disadvantage of the ordinary flapper (nozzle pressure reacts on the flapper and hence on the measuring system). Vane V moves between opposed nozzles N so that the thrusts of the nozzles on the valve are cancelled out. Fig. 233 shows the common ball-type pilot in which position of the ball B, controlled by the primary measurement, determines the pressure P_2 by varying the inlet oppositely to the leak L. Fig. 234 shows the unique hydraulic jet pilot used by Askania Regulator Co. A swinging jet pipe positioned by the primary measurement delivers more or less of its impact pressure to the pressure receiving device, depending on its position. Device moves a piston by swinging back and forth over a partition that separates pipes leading to the two ends of the piston.



FIGS. 235, 236, 237—ELECTRICAL AMPLIFICATION of minute electric signals to give suitable outputs for recording, control or telemetering. An elementary vacuum tube circuit, Fig. 235, permits amplification of a feeble a.c. voltage, usually 1 v. or more, and produces an output signal many times stronger. Amplification of signals in the millivolt range with minute power requirements takes place with a transistor (PNP type), Fig. 236. The transistor in suitably arranged circuits can produce power gains in the order of 10,000 times. The principal advantage is that the transistor does not require the power supply necessary for vacuum tube operation. The transistor responds at once with no lag for heating of cathodes and does not need to be kept in standby operation for response to input signals. The magnetic amplifier, Fig. 237, has two windings mounted on an iron core. The signal or control winding carries a d.c. input; the load winding, a.c. The impedance of the load winding varies with the degree of magnetic saturation of the iron core. As long as the core is not saturated, the impedance of the load winding is high, hence little current flows in load. When the magnetic flux in the core is increased to saturation by the d.c. signal, the impedance of the load winding drops sharply and load current increases in proportion. The magnetic amplifier controls load current between the limits of 3-97% of full value.

Conversion of remote electrical signals to another form of energy large enough to position valve stems or produce shaft displacements requires forms of relays. The relay then operates a pneumatic or hydraulic system to effect necessary motion.

FIG. 238—ELECTROHYDRAULIC RELAY (Robertshaw, A.&I. Div.). Input current causes unbalance of Microsen beam (see Fig. 205) and operates pilot valve. Oil supplied by gear pump is directed to power cylinder, thus producing movement of piston proportional to signal. Feedback spring, which is connected to output stem through a series of links, expands or contracts in response to stem movement and applies restoring force to the beam. Pilot valve ports are then closed and output piston is at required position.

FIG. 239—ELECTROPNEUMATIC RELAY (Swartout). Moving

coil carrying the input signal is positioned in a magnetic field. The lever arm moves in response to this force. A signal for increased output pressure forces the pilot valve stem down, increasing supply air to booster relay diaphragm. The booster valve-stem then rises and admits more air to control valve. When output pressure balances to new condition, booster valve closes on relay diaphragm, and feedback diaphragm moves away from pilot valve stem. System is then in balance at required pressure.

(c) Pneumatic Controllers

FIGS. 240, 241, 242, 243—PNEUMATIC CONTROLLER DEVELOPMENT. This sequence shows four steps in development of a controller from a relay-pilot-operated on-off controller, through a simple proportional type, to proportional plus reset, and proportional plus reset plus derivative. In Fig. 240, the nozzle-flapper combination of Fig. 231 is combined with the ball pilot of Fig. 233, the latter positioned by a bellows B to act as a relay. Air pressure P_1 flows both to the ball valve and through restriction R to nozzle N. Flapper F is positioned by the measured variable. Changes in position of F through the relay action of B and the ball valve produce such great changes in P_2 that such an arrangement cannot throttle easily and so is used for on-off control. To make this controller give proportional action, it is necessary to add feedback as in throttling bellows B_1 in Fig. 241. When a change occurs in the primary measurement, and flapper and relay change P_2 as a consequence, B_1 acts to move the flapper's moving pivot away from the nozzle. Each position of the measurement gives a definite flapper position and definite output pressure P_2. Note that in arrangement shown, moving flapper towards nozzle decreases P_2. To change control point of controller, some way of changing length of link 1 is used. To change proportional band (throttling range), distance from pivot 2 to pivot 3 is changed.

RESET RESPONSE. To obtain reset action in the controller of Fig. 241, an additional bellows B_2 and adjustable leak R are added as in Fig. 242. In Fig. 242, controller has droop, every value of load giving a slightly different control point. To obviate this, a "floating" component is added to the response by allowing the flapper pivot to move temporarily, as in proportional action, but after a time returning the pivot to its original position. P_2 is now applied through a new bellows B_2 to B_1, giving initial response as in Fig. 241. However, after a time determined by setting of leak R, pressure in B_1 returns to atmospheric and flapper pivot returns to initial point. Leak rate is "reset time."

DERIVATIVE RESPONSE. Fig. 243. Adding derivative or rate response to controller of Fig. 242 consists merely in adding an adjustable restriction between output line P_2 and reset bellows B_2, thus slowing down effect of proportional action with a change, and giving initial rapid change in P_2 almost as in Fig. 240. After a time, this effect wears off as P_2 reaches bellows B_2. Time for equalization is "derivative time." Most actual pneumatic controllers work much as these simplified sketches show, with proper adjustments added. Many actual variations in design detail exist.

FIG. 244—STACK-TYPE FORCE-BALANCE CONTROLLER (Moore Products Co.). Controller shown has pneumatic set-point and variable measurement, proportional and reset action, with relay valve (See Fig. 218). Set pressure P_1 is balanced against measured variable pressure P_2 by means of diaphragms D_2 and D_4. Restriction V_1 controls proportional band, and V_2 controls reset time. Pressure relations on diaphragms D_2, D_3 and D_4 control leak rate through nozzle L_1 and hence pressure over D_1. In turn, this controls output P_3 by either admitting air at M or exhausting at bleed B through porous center of D_1. Pressure P_3 under D_3 opposes any change. D_3 controls L_2, thus controlling pressure over D_4 in relation to flow rates through V_1 and R.

FIG. 245—BEAM-TYPE FORCE-BALANCE CONTROLLER (Foxboro Co.). This controller uses a beam in form of circular annulus, pivoted above by rotatable pivot arm P and pushed upward against pivot arm P by four bellows, A, B, C and D. These are in contact with annulus. With pivot points over bellows A and D, proportional band is zero. With pivot points over bellows B and C, proportional band is infinite. At intermediate locations, practical proportional band percentages are obtained. Bellows B contains set pressure, and bellows C, measurement pressure. Bellows A is throttling bellows; and bellows D, reset bellows. Relations of these four pressures and the pivot points determine leak at nozzle N. Supply air flows through restriction R to nozzle N, also to relay valve. Nozzle pressure determines valve position in relay, and hence relation of bleed B and pressure delivered to control valve and bellows A. Any change in set vs. measurement pressures B and C causes beam to tilt depending on proportional band setting. Bellows A opposes change while D initially puts in no correction of its own, but gradually opposes A (aids change) as reset time runs out.

(d) Electric Controllers

FIG. 246—ELECTRIC CONTACT CONTROL, HIGH-LOW TYPE. One of several ways in which contacts can be closed mechanically in electric measuring instruments having a pointer. Pointer P swings freely except at intervals when a chopper bar C descends, pushing it against a contact table T. Table tilts if pointer is high or low, making corresponding contact with enough force to complete necessary circuit either through a relay or by direct action.

PHOTOELECTRIC CUTOFF. Various types of control can be applied by means of photocell and light beam; for example, in scales where a relay is tripped at set weight.

FIG. 247—OSCILLATING-COIL CONTROL PICKUP (Wheelco Instrument Div.). Instrument pointer carries a vane that swings freely between coils in an oscillating electronic circuit. Coils are on control-point set arm. If vane V leaves coils, circuit oscillation changes, operates a relay to increase or decrease, turn on or shut off flow of control medium. In two-position control, vane movement of 0.006 in. will operate relay.

FIG. 248—ELECTRIC-HEAT CONTROL, DURATION-ADJUSTING TYPE (Leeds & Northrup Co.). Controls % of time during a short cycle in which electric heat will be on, to give proportional control without current flow adjustment. Measuring circuit sets slide wire S_1, which in turn sets S_2 in control bridge. Relay detector detects unbalance calling for heat and closes circuit to furnace, at the same time providing heat to a slow heater H_1 and a fast heater H_2, which provide heat to two bridge-circuit resistances R. Effect of heat in resistances is to rebalance bridge and cut off contactor C after time proportional to demand. Second slower heater adds response also for time that temperature has been on control point so as to reduce time to return temperature to desired value. Condensers and resistances in output of second bridge supply reset, derivative and feedback. Combined outputs of two bridges is fed to amplifier for control of final element.

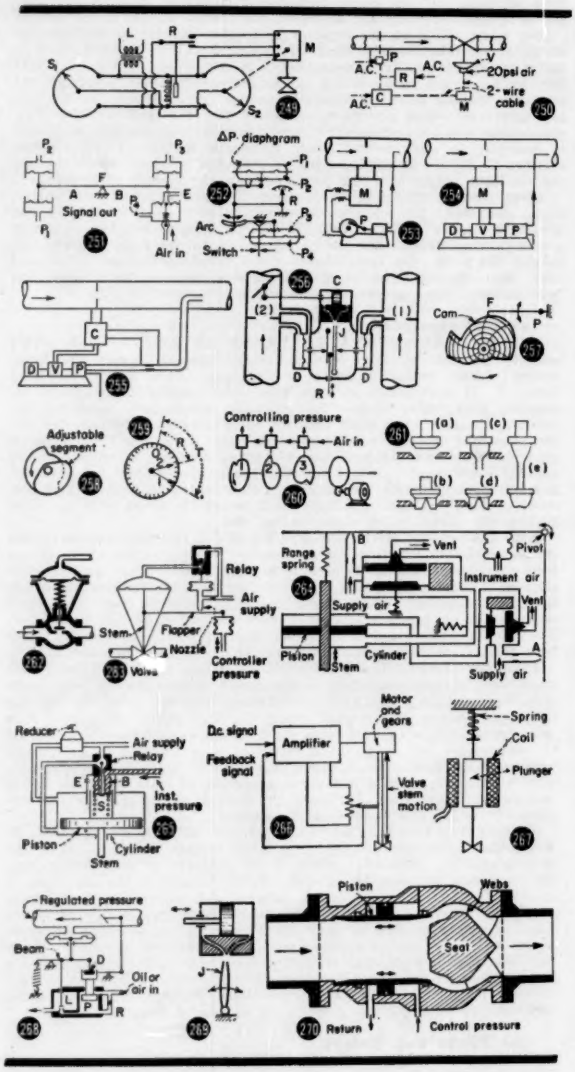


FIG. 249—PROPORTIONAL ELECTRIC CONTROL. Various ways are used for obtaining proportional control electrically with bridge circuits. A simple circuit with proportional action only uses a bridge in which the measured value sets slide wire S_1. Bridge unbalance is detected by relay R that operates motor valve M in proper direction, at the same time changing slide wire S_2 until balance is reached, when the valve motor stops.

FIG. 250—ELECTRONIC-PNEUMATIC CONTROL (Swartout). Primary sensitive element is a resistance thermometer or some element such as a pressure gage, manometer or other device that provides a potential proportional to measured value, either direct, or with a differential transformer used as a transducer. Measurement is transmitted as a.c. over two wires to controller, and also to recorder. Control impulse, which is d.c., goes over two wires to manual control station and to a power relay at final control element that controls air supply to pneumatic control valve. System eliminates instrument lags, gives claimed accuracy of ½%.

(e) Ratio Control

FIG. 251—RATIO TOTALIZER (Hagan Corp.). Balance-beam device operated by combination of pressures or other forces gives a combined output P_4. Fulcrum F can be moved to change lever arms. Can be used to add, subtract, multiple or average pressures, or can be connected up as a pneumatic-set, pneumatic-measure controller of proportional, or proportional plus reset type. Combination of two gives proportional plus reset plus derivative. Balance of pressures P_1, P_2 and P_3 determines output pressure P_4, which thus serves as a force-balance transmitter.

FIG. 252—RATIO CONTROL MECHANISM (Hays Corp.). Similar in general effect to Fig. 256, but differs in detail. Different pressure or pressure diaphragms are ratioed by linkage having a setting pointer and a link moving in a curved slot. If ratio is not correct, contactor attached to captive stream diaphragm makes high or low contacts to control damper motor.

FIG. 253—PROPORTIONING PUMP, PACED BY METER. Contact-making meter gives impulse to proportioning pump each time a certain flow quantity passes through main line 1. Then pump injects a fixed quantity of treating solution into line 1 through line 2. Many variations of this principle exist.

FIG. 254—CONTINUOUS-FLOW PROPORTIONING. Meter in main line either drives a differential gear V or adjusts a variable-speed transmission V, interposed between driver D and pump P. Methods such as this can give infinite range of ratios, with accuracies on the order of 0.01%.

FIG. 255—CONTINUOUS FLOW PROPORTIONING WITH FEEDBACK CONTROL of secondary flow. Controller C maintains desired ratio between primary and secondary flow. Controller C in response to differential signal from main stream paces variable-speed transmission V located between driver D and pump P. Differential tap in secondary stream continuously senses secondary flow and transmits signal to controller. Controller, comparing primary and secondary flow to desired ratio, makes corresponding adjustment in pump speed.

FIG. 256—FLOW (PRESSURE) RATIO CONTROL (GPE Controls, Inc.). Ratio of pressures or differential pressures in pipes 1 and 2 sets position of jet pipe J (See Fig. 269). Effect of two pressures may be adjusted by pivot point determined by ratio adjuster R. Jet pipe positions the piston in power cylinder C to adjust damper in captive stream 2 for desired ratio.

CASCADE CONTROL, in closed-loop systems, involves adjustment of the set point of one controller in response to a signal from another controller. Each controller measures separate but related variables. Cascade systems can be used to maintain a desired relationship between two variables (for an example, see Fig. 255); limit accurately a secondary variable; reduce load changes, nonlinearities and discontinuities near their source; and improve the control circuit to reduce time lag.

(f) Time Relations

GENERAL: Many operations are conducted as variable against time. In other cases, timers are used to start and stop processes without time-sequenced adjustment of control point. Fig. 257 shows a typical cut cam for use on a round-chart recorder-controller equipped with a control point follower. Cam is printed with chart for ease in cutting to desired time-variable relation. In some cases, where processes may change from time to time, it is possible to use an adjustable cam similar to the type shown in Fig. 258. Interval timers usually are provided with a time dial and one or more hands that move counter clockwise. Fig. 259 shows one type. Hand 1 is set to total time T. Hand 2 moves to position 1 and starts process. When hand 2 reaches 0, process stops. At any intervening time R, hand 2 shows remaining time. In processes involving many time-sequenced parts, program controllers as in Fig. 260 are used. Here a motor drives a shaft carrying cams 1, 2 and 3. Such cams can be used to vary control points of pneumatic-set controllers as well as to start or stop various portions of the process at predetermined times. Cams can also be used to operate electric switches.

27—Fluid Control Elements

GENERAL: Most commonly, the final control element in an industrial control system is a valve, since a fluid is likely to be the control medium. Here, however, it may be a positioning device for other purposes, a switch, rheostat, variable-speed drive, damper, etc. Since valves are the most important of these elements, this section will be confined to them, although it should be understood that most of the operators described can be applied to other final elements than valves.

VALVE CHARACTERISTICS. Control valves are of many designs, but in general their characteristics may be described as beveled disk, V-port, equal-percentage plug, equal-percentage V-port, and linear plug. For throttling service, control valves are usually double-seated so as to be substantially balanced against line pressure. Valves may open on increase in pressure of the control medium, or they may close with medium pressure increase. In most control applications today, the so-called characterized valves are used. Fig. 261 shows the main inner valve types: *a* is a beveled disk, *b* a V-port, *c* and *d* equal-percentage plug and V-port inner valves, and *e* a linear plug. Sketch *e* shows both parts of the double plug as used in balanced valves.

(a) Pneumatic Operators

VALVE DESIGN. Many control valves incorporate special features such as finned bonnets for cooling of the stuffing box on service above about 400 F.; special methods of reducing stuffing-box friction or possible leakage, such as bellows-type seals, grease seals and special packing; extension bonnets to prevent freezing; and special types of closure device, such as pinch valves, flexible-diaphragm valves (Saunders type), and dampers, etc.

FIG. 262—DIAPHRAGM-TOP VALVE. Commonest type of control valve operator is the diaphragm top, making the value a "diaphragm motor valve." Diaphragm tops are of two types: air-to-open and air-to-close. In either case, the motion of the diaphragm is opposed by a calibrated spring so as to make valve stem position proportional to pressure. An interesting modification in diaphragm valve tops is the Isoforce actuator (Foster Engineering Co.) that combines some of the features of the conventional top (Fig. 262) with the piston top (Fig. 265). This top uses a diaphragm over a piston. The diaphragm seals the piston frictionlessly, permitting full stroke, and use of higher pressure to operate the control valve.

FIG. 263—VALVE POSITIONERS. Owing to friction in stuffing box of a control valve, it is difficult to position the stem accurately in proportion to controller output pressure. Also, there will be hysteresis. A positioner can be used to make stem position accurately responsive to pressure. Positioners vary in detail, but in general are similar in principle to Fig. 263 in which controlled output pressure is applied to one end of a beam supported at other end by valve stem. Beam acts as a flapper in conjunction with a nozzle and relay air valve. In air-to-close valve shown, increase in pressure lifts beam, raises nozzle pressure and lowers valve stem (feedback) to bring definite stem position in response to pneumatic signal from controller.

FIG. 264—PNEUMATICALLY OPERATED PISTON (Fisher Governor Co., others). Signal from control instrument acts on bellows, causing the two beams at right angles to move about pivot. Action of each beam is to open nozzle at B and close nozzle at A, or conversely. Supply air is admitted to one side of piston and removed from the other side by action of pilot relays connected to nozzles at A and B. Range spring, attached to piston-rod extension, feeds back piston movement to upper beam to balance incoming air signal and, thus, to position the valve stem. Full plant air pressure can be used on piston to provide greater power to position the control valve if high fluid forces are present that act upon the valve.

FIG. 265—PISTON-TOP VALVE (Annin Co.). Longer stem travel, together with more power for large valves, can be secured with a piston-type valve motor. Design shown has built-in positioner giving stem position directly proportional to controller output pressure. Piston is loaded on top with constant pressure in L from reducer. Instrument pressure inside double bellows B is balanced against calibrating spring S, positioning pilot valve that controls admission of air either under piston, or to exhaust, E. Position accurate to 0.001 in.

(b) Electric and Hydraulic Operators

COMBINATION VALVE OPERATORS. With the coming of electronic control, a need has developed for setting the opening of the final control element from a small electric signal. Although there is some development in all-electric valves for this purpose, most of the effort thus far has been in combination operators that receive an electric signal and produce a controlled output of air or a liquid under pressure. Some of these relay devices have been discussed in Sect. 26(b). See Fig. 238 for an electrohydraulic operator, and Fig. 239 for an electropneumatic operator.

FIG. 266—ELECTRIC VALVE OPERATOR (Conoflow, others). The d.c. signal from the controller is amplified and operates a geared motor driving the valve stem. Valve position is converted to an electrical signal that feeds back into the amplifier circuit where it is compared with the signal. Any difference is amplified to drive the valve to a position exactly proportional to the original d.c. signal. Provision is made to operate valve by handwheel, independently of controller.

Another version (Lear Industrial) uses a continuously rotating a.c. motor, coupled to a pair of dry magnetic particle clutches. One clutch closes valve in proportion to signal; other clutch opens valve. Acme thread jackscrew imparts linear motion to valve stem.

FIG. 267—SOLENOID VALVES (Automatic Switch Co., others). Solenoid valves are of many types, but most are open-and-shut, either opening with current in the coil, or when the circuit is broken. Consequently, they are commonly used as dump valves and for emergency purposes, leaving throttling applications to conventional control valves. Where more power is required, solenoid valves can be pilot operated.

FIG. 268—HYDRAULIC VALVE OPERATOR (Republic Flow Meters Co.). Hydraulic operator can be applied to valves, dampers and the like. Primary indication is applied through a spring-balanced beam to a rod controlling leak at L. Oil (or air) pressure is applied both above and below piston F, area above being less. Restriction in line to cylinder below piston makes control of under-piston pressure possible with aid of leak. Piston movements are converted to position of final control element. Through a dash pot they are also transferred to beam for applying feedback action.

FIG. 269—HYDRAULIC VALVE OPERATOR (GPE Controls, Inc.). Primary measurement positions jet pipe J, which projects liquid under 100 lb. pressure against openings leading to two sides of piston. When jet strikes half way between, pressures are equal. Minute deflection will alter pressure on one side or other and drive piston to new position. For most applications, where piston should be able to assume intermediate positions, some sort of mechanical feedback would be used to make piston position accurately proportional to jet pipe position. Can be used for driving valves or other final control elements against high pressures, since about 90% of static pressure in operating liquid is recovered as effective pressure against piston.

FIG. 270—INTEGRAL OPERATOR AND VALVE (Bendix Corp.). In the Bendix Fluidal valve, an annular piston varies the flow opening between the valve body and a seat that is supported in the fluid stream by webs. Pneumatic or hydraulic control pressure moves the annular piston against the seat in proportion to incoming signal. The balanced piston with integral control annulus gives minimum hysteresis and fast response. Pressure range is from 25 to 12,000 psi., temperatures from −65 to 400 F. Valve can respond to frequencies as high as 120 cycles/sec. in electro-hydraulic control system. Provision for remote indication of valve position by electric or pneumatic transmitter.

(*Continued on p.* 238.)

Companies Supplying Information Especially For This Guide

American Chain & Cable Co.
American Instrument Co.
American Machine & Metals, Inc.
American Standard Controls Div.
Applied Research Laboratories

B

Bailey Meter Co.
Baldwin-Lima-Hamilton Corp.
Barber-Colman Co.
Barnes Engineering Co.
Barton Instrument Corp.
Bausch & Lomb, Inc.
Beckman Instruments, Inc.
The Bendix Corp.
B-I-F Industries
The Bin-Dicator Co.
Bowser, Inc.
The Bristol Co.
Brookfield Eng. Laboratories, Inc.
Brooks Rotameter Co.
Buffalo Meter Co.
Burling Instrument Co.
Burrell Corp.
B/W Controller Co.

C

Cambridge Instrument Co.
CompuDyne Corp.
Conoflow Corp.
Consolidated Electrodynamics
Cutler-Hammer, Inc.

D

Daystrom, Inc.
Dracco Corp.

E

Engelhard Industries, Inc.

F

Fenwal, Inc.
Ferranti Electric, Inc.
Fischer & Porter Co.
Fisher Governor Co.
The Foxboro Co.
Fuller Co.

G

Gardner Laboratories, Inc.
General Controls Co.
General Electric Co.
Gilbert & Barker Mfg. Co.
Gow-Mac Instrument Co.
GPE Controls, Inc.
Grinnell Co., Inc.
Gulton Industries, Inc.

H

Hagan Corp.
Halliburton Co.
Hallikainen Instruments
Hardinge Co.
Hastings-Raydist, Inc.
The Hays Corp.
Hydromatics, Inc.

I

Industrial Instruments, Inc.
Industrial Nucleonics Corp.

J

Jerguson Gage & Valve Co.

K

W. A. Kates Co.
King Engineering Corp.

L

LaMotte Chemical Co.
Lapp Insulator Co.
Leeds & Northrup Co.
Loe Engineering Co.

M

Manning, Maxwell & Moore, Inc.
Manostat Corp.
McGraw-Edison Co.
Milton Roy Co.
Mine Safety Appliances Co.
Minneapolis-Honeywell Regulator Co.
Moore Products Co.
MSA Research Corp.

N

Norcross Corp.

O

Ohmart Corp.

P

The Partlow Corp.
Perkin-Elmer Corp.
Petrometer Corp.
Philips Electronics, Inc.
Photomation, Inc.
Powertron Ultrasonics Corp.
Precision Scientific Dev. Co.
Precision Thermometer & Instrument Co.
Pyrometer Instrument Co.

R

RdF Corp.
Republic Flow Meter Co.
Research Appliance Co.
Robertshaw-Fulton Controls Co.
Rotron Controls Corp.

S

Shand & Jurs Co.
F. J. Stokes Corp.
Strahman Valves, Inc.
Syntron Co.

T

Tempil Corp.

V

Vapor Recovery Systems Co.
Varian Associates
Vibra Screw Feeders, Inc.

W

Wallace & Tiernan, Inc.
West Instrument Corp.

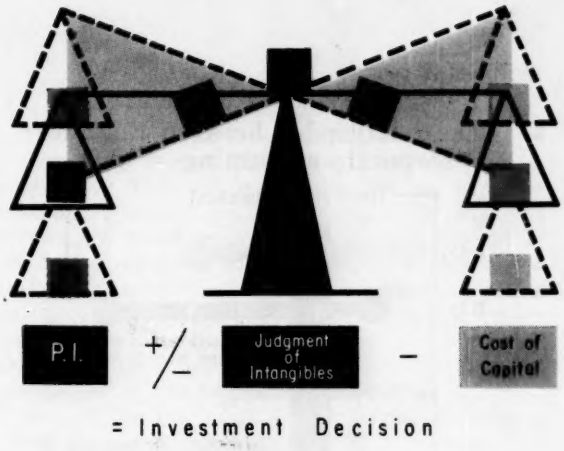
Y

Yarnall-Waring Co.

Literature

Many companies offer a wide range of control devices—from individual components to complete systems. These companies provide detailed and informative literature about their products. For a listing of currently available information, consult the listing of manufacturers' literature starting on p. 320. Use the Reader Service Cards for a fast direct reply from the companies offering literature.

Reprints. To order reprints of this 52-page report on process control and instrument elements, circle reprint number 183 on Reader Service Postcard in this or any issue. Price, $1 per copy.



The Role of P.I. in Investment Evaluation

The Profitability Index is one of the most logical and useful tools to help you evaluate an investment. You may find there's more to the P. I. than you realize.

WILLIAM D. McEACHRON, *Standard Oil Co. (Indiana).*

Let's say you have three cost-reducing proposals in front of you. Each one involves considerable investment in new machinery—it is up to you to choose the most promising. If the costs and savings estimates have been made carefully, if you know not only how to calculate the Profitability Index but also its full significance, and if furthermore your judgment in assessing intangibles is good, you will probably make the right decision.

The Profitability Index (P. I.) goes under various names—other authors have called it Discounted Cash Flow Rate of Return; the Investor's, or the Interest, Rate of Return; and in one case, the True Rate of Return.

The P. I., you may recall, involves setting up a cash flow schedule on which the various outlays have minus signs and the cash returns (including salvage value) have plus signs. The discounting rate that will reduce this schedule to a present value of zero is the P. I.

Most other common investment yardsticks are easier to compute but have less meaning.

For instance, take payout times—very easily calculated by accumulating the annual cash returns until the accumulation matches the amount spent. However, payout times only tell you how soon the investment will be recovered, and this is of less importance than the extent of the anticipated profits.

Even relating the total savings to the investment to obtain the Average Earnings Rate of Return may be misleading, as the precise timing of costs and returns may be just as important as their magnitude.

For example, let's say that Project A brings in $10,000 a year for ten years while Project B, involving the same investment and risks, brings in $120,000 in the tenth year as its sole return. Although B would show a higher average rate of return, Project A may really be more attractive because the money starts coming in sooner.

The Profitability Index takes this time factor into account to arrive at a meaningful rate of return.

The one other general investment evaluation procedure that is based on the concept of the time value of money is the Present Value technique. Here, the discounting is done at a prescribed rate, usually the cost of capital, and the answer represents the present value in dollars of the total project cash flow. While the calculations are thus simpler—no trial-and-error or interpolation is involved—the Present Value lacks the full power of the P. I. as an investment tool.

This power and usefulness derive from two distinct but related characteristics of the P. I. estimate. The first of these is that the P. I. is expressed in terms that have meaning in their own right and are consistent not only from project to project, but from project evaluation to corporate accounting as well. The second favorable characteristic is that the P. I. lends itself particularly well to the weighing of risks at the decision-making level.

The P.I. and Corporate Accounting

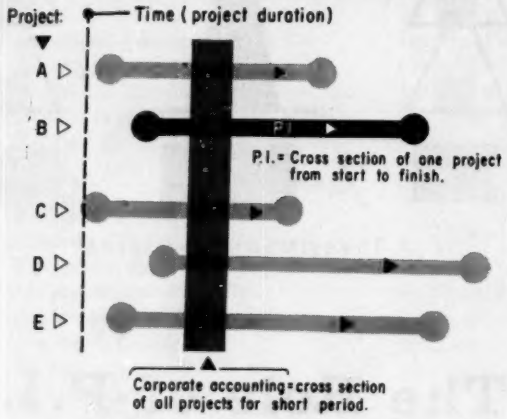
Although both measure business economics, P. I. and accounting represent two quite different cross sections of the total corporate enterprise.

This difference is illustrated in Fig. 1. There, the vertical dimension represents the total investment that goes to make up the company, separated into individual projects or investment decisions. The horizontal dimension represents a portion of the time spectrum, which in real life extends indefinitely into the future, as well as going back to the inception of the company.

Corporate accounting, as summarized in a company's annual report, represents an annual cross section of the total firm, and measures the current health of the enterprise. It is illustrated by the shaded vertical rectangle in Fig. 1. Since the time dimension is very short—only one year or less—the problem of time weighting is not directly involved.

This article is based on a paper "The Profitability Index Technique" given by the author at the Chicago Chapter meeting of the American Assn. of Cost Engineers.

The relationship between P.I. and corporate accounting—Fig. 1



In contrast, Profitability Index—or any investment evaluation for that matter—represents quite a different cross section. We have shown this by the black horizontal rectangle. Here, we are concerned with a single investment venture throughout its life, and the time value of money becomes of crucial importance.

These two different cross sections or viewpoints can be compared by a simple illustration, as shown in Table I. We will assume a single depreciable investment of $100,000, which after a one-year startup delay earns an after-tax operating profit (or cash income before depreciation) of $40,000 for four more years. After this, revenue ceases and the investment has no further value. Total net profit is $60,000, equal to total cash income less the investment.

To determine the actual return on investment, we would have to divide profit by investment on an annual basis. Although we know the total net profit over the five-year period, we don't really know the net annual profit, as we have not yet decided on a depreciation schedule. The investment to be used is even more obscure. Initially it was $100,000. At project termination, it was zero. Hence, we obviously can't use the same value all the way through.

We can solve both these problems by drawing up a year-by-year schedule for the life span of the project. To do this, we must decide how to handle depreciation —how to charge off revenue to recover the investment.

Under conventional accounting, the year-by-year depreciation charge is computed solely on the basis of time, without reference to income. Straight-line depreciation would yield the schedule shown in Table II. Note that after the loss in the first year, the annual rate of return rises with time, because a constant profit has been related to a declining investment.

Such a varying rate of return is of little value to the decision-maker who must match the value of the project *in its entirety* against the cost of capital. The average value of 24% is also inadequate since the higher rates of return occur late in point of time and carry less weight than the earlier, lower, values.

Constant Rate of Return Needed

For evaluation purposes, we can set up a schedule for the return of capital any way we want to without changing the intrinsic value of the project itself. Hence, we can develop a depreciation schedule that year by year provides a constant return on investment. Table III shows this schedule for our example. Note particularly that we have a negative value for depreciation during the first year. This situation is analogous to plowing back earnings into the project.

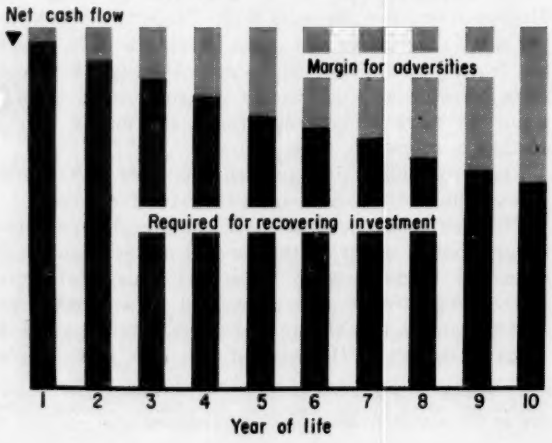
For the usual type of investment situation, there is only one depreciation schedule that will yield a constant rate of return through time. Likewise, there is only one rate of return that can be so generated. It represents the average rate of return for the project in its entirety and, since it is constant through time, there is no problem with time-weighting. This rate of return is the Profitability Index. Thus, the P. I. for our example is 16.3%.

The indicated closing investment shown in Table 3 represents what the investor has at stake in this particular project at the end of each year. The $100,000 is only the initial outlay. For a year, the investment increases in value as the period of earnings draws closer. Thereafter, the investment is gradually recovered as the project is liquidated.

What is done with the capital recovered has no bearing on the attractiveness of this particular project. The income from investing it in some other venture concerns only that other venture—not this one.

Some companies actually do develop the P.I. estimate by setting up a schedule by trial-and-error as we did. However, most have found it more convenient to use a discount factor approach.

Margin for adversities increases with time—Fig. 2



As shown in Table IV, calculations using discount factor tables yield the 16.3% answer with little work.

An investment proposal—Table I

Year	Investment, $	Cash Income, $	Net Profit, $
0	100,000		
1		0	
2		40,000	
3		40,000	
4		40,000	
5		40,000	
Total	100,000	160,000	60,000

Application of conventional straight-line-depreciation—Table II

Year	Cash Flow, $	Income, $	Depreciation, $	Closing Investment, $	Rate of Return, %
0				100,000	
1	0	−20,000	20,000	80,000	LOSS
2	40,000	20,000	20,000	60,000	28.6
3	40,000	20,000	20,000	40,000	40.0
4	40,000	20,000	20,000	20,000	66.7
5	40,000	20,000	20,000	0	200.0
Total	160,000	60,000	100,000		
Average		12,000		50,000	24.0

Note: Rate of return shown is the ratio of income to the average of opening and closing investments for each year.

P.I. can also be considered as the time-weighted average rate of return over the life of the project, regardless of what depreciation schedule is used.

To illustrate, let us reconsider the rate of return schedule developed by conventional straight-line-depreciation accounting, as shown in Table V.

The first three columns of this table repeat the earlier calculation of annual rate of return using accounting data. The last two columns show book profit and investment in terms of their present value, using a 16.3% continuous discount factor.

We can see that the ratio of average profit to average investment in these terms is also 16.3%, representing the P.I. In this example, 16.3% is the only value that when used to derive the average present value of profit and investment will also yield itself as the ratio between these two derived values.

In summary, therefore, Profitability Index has a really basic value for the decision-maker—it represents the effective average ratio of profit, after provision for return of capital, to outstanding investment. In effect, it represents an extension of the concepts of corporate accounting to cover the life span of the project in such a way as to recognize the time value of money.

The Role of P.I. in Investment Decision

So much for what the P.I. means. Now, let's look more sharply at how it affects investment decisions.

These decisions must be made in the light of the corporate profit goal. Just what is this profit goal, specifically? It is not maximizing income, nor even maximizing return on investment. If it were the former, we should try to achieve every last penny of net income regardless of how much investment it took to do it, and regardless of how low a return was earned on that investment. In contrast, if maximizing return on investment were the objective, we should select only that single investment opportunity that afforded the highest return and forego all others.

Instead, the true profit goal is maximizing income above the cost of capital invested to generate that income. Our objective should therefore be to undertake only those investments that, after consideration of all risks, promise to earn more than the costs of capital, and to reject all those investments that are expected to earn less than the cost of capital.

From this, it follows that the problem of making an investment decision is a matter of testing the profits anticipated against the cost of capital. This is essentially a balancing operation in the hands of the decision-maker.

Suppose we are confronted with a project that carries a P.I. estimate of 16%. Suppose further that our

Application of time-adjusted depreciation—Table III

Year	Cash Flow, $	Income, $	Depreciation, $	Closing Investment, $	Rate of Return, %*
0				100,000	
1	0	17,740	−17,740	117,740	16.3
2	40,000	17,360	22,640	95,100	16.3
3	40,000	13,300	26,700	68,400	16.3
4	40,000	8,590	31,410	36,990	16.3
5	40,000	3,010	36,990	0	16.3
Total	160,000	60,000	100,000		
Average		12,000		73,650	16.3

* Based on average of opening and closing investment for year.

P.I. solution using discount factors—Table IV

Year	Cash Flow, $	16% P.I. Discount Factor	16% P.I. Present Value, $	17% P.I. Discount Factor	17% P.I. Present Value, $
0	−100,000	1.000	−100,000	1.000	−100,000
0–1	0	.924	0	.920	0
1–2	40,000	.788	31,500	.776	31,000
2–3	40,000	.671	26,800	.655	26,200
3–4	40,000	.572	22,900	.552	22,100
4–5	40,000	.487	19,500	.466	18,600
Total			+700		−2,100

By interpolation, P.I. = 16.3%

Note: Year designations shown as 0-1, etc., denote uniform cash flow during the year starting at time 0 and ending at time 1, etc. This convention helps to insure use of the proper discount factors. The latter are obtained from discount tables based on continuous compounding. (For instance, see *Engineering Economist*, Vol. 5, Nos. 2, 3 and 4.)

Time-weighting of accounting rate of return—Table V

Year	Income, $	Average Investment, $	Rate of Return, %*	Present Value at 16.3 Income, $	Present Value at 16.3 Investment, $
1	−20,000	90,000	LOSS	−18,500	83,000
2	20,000	70,000	28.6	15,700	54,900
3	20,000	50,000	40.0	13,300	33,300
4	20,000	30,000	66.7	11,300	17,000
5	20,000	10,000	200.0	9,600	4,800
Average	12,000	50,000	24.0		38,600
Time-weighted average			16.3	6,280	

* Based on average of opening and closing investments for each year.

capital cost is 10%. Direct comparison of the two would, of course, favor undertaking the project.

In actual practice, we know that the problem is not this simple. The decision-maker does much more than merely compare two numbers that are handed to him, however meaningful those numbers may be. He must take into account the uncertainties in the P.I. estimate, the possibility of operating failure, the prospects of premature obsolescence, the sensitivity of the project to environmental factors such as product demand and pricing, and a host of even more intangible factors.

All of these combined go to make up the element we call judgment. If we think of the evaluation process in terms of a balance, judgment acts as a counterpoise, which can either subtract from or add to the P.I. estimate of the project. This is symbolized in our opening sketch. Instead of two components in the economic balance, we now have three: the P.I. estimate, the cost of capital, and the element of judgment. For the marginal project, judgment precisely offsets the difference between the P.I. estimate and the cost of capital.

Hence, the key question facing the decision-maker is whether unforeseen adversity not provided for in the P.I. estimate will be enough to swing the balance against the project. The evaluation is really a question of testing the economic balance of the project in the light of this judgment.

Significance of the Driving Force

Returning to our hypothetical project with the P.I. of 16%, we know that the P.I. estimate indicates this project can earn the cost of capital plus something in addition. It is this something extra—expressed as a differential of six P.I. percentage points—that represents the driving force favoring investment. What is the nature of this driving force?

Mathematically, the P.I. for any project will be reduced by six percentage points by reducing the cash flow schedule by 6% per year. Thus, at the end of the first year, cash flow would be reduced to 94% of its original value, at the second year to 94% squared at the third year to 94% cubed, and so on.

Fig. 2 shows this 6% attenuation applied to the cash flow for our 16% project. The total height of the bars depict, of course, the cash flow of the original estimate. The lower solid black portion of the bars represents a cash flow schedule that would yield a project P.I. of exactly 10%, matching our assumed cost of capital.

The remaining gray areas of the bars can be considered to be the margin for adversities embodied in the original estimate. This much of the predicted cash flow could be lost before the project would fall below the cost of capital. Or, if the predicted cash flow were actually realized, this would be the profit above and beyond the cost of capital.

Thus, in terms of the P.I. estimate itself, we can see that the apparent profit is equivalent to the margin available to absorb unforeseen adversities in the future, assuming that the cost of capital must and will be met.

This is not to imply that when adversity strikes, it does so in an idealized geometric pattern. For the individual project, many possibilities exist. For the aggregate of many projects, the geometric pattern of decay in real earning power seems rational. As risk is a function of investment magnitude and time, expectations in the far-distant future are more uncertain than those that are short term.

In summary, the decision-maker who has to inject his own considerations of judgment into the economic balance is likely to find the P.I. an extremely useful concept. If the problem is purely analytical, the Present Value approach discussed earlier may be less cumbersome and more straightforward. But until the day comes when we can quantify intangibles and forecast the future with much more precision than we can today, Profitability Index should remain a powerful investment evaluation tool.

Meet the Author

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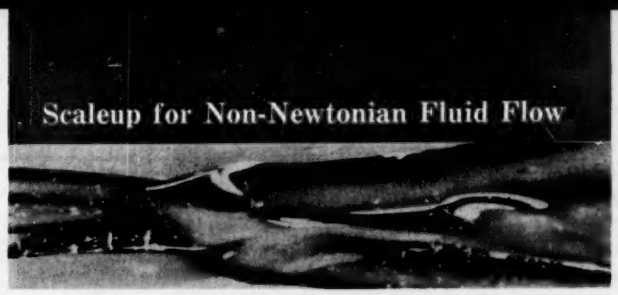


Articles in This New Series

- ▶ **1. Designing Laminar-Flow Systems.**
- 2. Determining end of laminar region.
- 3. Prior art on turbulent flow.
- 4. Scaleup of non-Newtonian turbulent flow.
- 5. Handling settling slurries.
- 6. Methods for obtaining data.
- 7. How to interpret data.

Designing Laminar-Flow Systems

First article in a new series. New method for scaling up non-Newtonian fluid-flow data in laminar region avoids trial-and-error, gives practical flow-curves.

RICHARD LeBARON BOWEN, JR., *Coated Textile Mills, Inc.*

When scaling up a fluid-flow system for Newtonian fluids, engineers have a wealth of straightforward information, including a number of good correlations, to draw on.[1] However, when a piping system has to be designed for handling a non-Newtonian fluid, an engineer must become a rheologist of sorts, to be able to cope with the bewildering array of correlations available.

He must be able to recognize a pseudoplastic or Bingham material, and fit an equation to viscometric data, or determine constants at point values for materials that do not conform to either of these classic materials.

In a new method presented here for pipeline scaleup, we determine a flow diagram from viscosity data and go one brief step past this, to get a complete set of pipe-flow curves for various pipe sizes. No trial-and-error methods are required. And the resulting curves clearly indicate how variations in pipe size, pressure drop and flow rate affect each other.

First Part of Series

In this first part of a series on non-Newtonian-flow scaleup, we will discuss problems and techniques for handling laminar flow. Forthcoming articles will take up turbulent flow and how to obtain data.

To understand these new methods, however, it will be useful to briefly define some terms and review some of the well-known correlations in this fluid-flow field.

A non-Newtonian fluid is one where rate of shear is not always proportional to applied stress. Thus, consistency is not independent of shear stress and rate of shear.

There are three important non-Newtonian fluids. A Bingham plastic shows no flow until a given stress (yield point). A pseudoplastic material often has no yield point. A dilatant fluid behaves so that a large increase in shear stress at a high flow rate results in a small increase in shear rate.

Non-Newtonian fluids comprise polymer solutions, paints, pigment dispersions, coating solutions, slurries, suspensions, and a large variety of other commonly encountered systems. In fact, it may be said that any extremely viscous fluid is very probably non-Newtonian. Newtonian fluids are extremely rare above 20,000 cp.

Correlation Good for All Fluids

Alves, Boucher, and Pigford[2] made the first attempt at general methods for pipeline design applicable to all fluids in the laminar region, whether Newtonian or non-Newtonian.[m]

In their method, a plot is made of various values of $8q/\pi D^3$ vs. $D\Delta P/4L$ based on data from extrusion rheometers (also called capillary-tube viscometers) or actual pipeline tests. A single curve results for all lengths and diameters of pipes in the viscous region if the fluid is time-independent—that is, if the shear stress ($D\Delta P/4L$) is constant with time at any rate of shear. Such curves are unique functions that are independent of system geometry and their shape depends upon the rheological properties of the fluid tested.

By a simple graphical manipulation, such plots can be converted to true shear-stress—shear-rate diagrams (a rheogram or shear diagram). Alves et al. point out that these $8q/\pi D^3$ vs. $D\Delta P/4L$ plots can be used

directly for calculating pipe diameter for a given pressure drop or pressure drop for a given diameter (at any chosen flow rate).

An empirical method of pipeline design for non-Newtonian fluids has been devised by Metzner.[6] Data from a rotational viscometer is used with pipeline data to scale up to other values. The important contribution of this work is that scaleup must be made at a constant ratio of V/D, rather than at a constant value of V as frequently recommended.[7] The reason for this important criterion will become apparent below.

Another similar method of pipe sizing has been reported by Symonds et al.,[35] but is limited solely to pseudoplastic fluids obeying the "power law":

$$\tau = K(dv/dr)^n \qquad (1)$$

where the relationship between shear-stress (τ) and shear-rate (dv/dr) comes from rotational-viscometer data. Both methods have in general been supplanted by more-useful procedures.

General Equation for Flow

Metzner and Reed produced what probably is the first general correlation for all non-Newtonian fluids.[8] They use a modified form of the conventional friction factor and Reynolds number plot for Newtonian fluids. Friction factor comes from the usual Fanning equation:

$$f = \frac{D\,\Delta P/4L}{\rho V^2/2g_c} = \frac{D\,\Delta P g_c}{2\rho V^2 L} \qquad (2)$$

while the Reynolds number is defined by

$$N_{Re,M} = \frac{D^{n'}V^{2-n'}\rho}{g_c K' 8^{n'-1}} \qquad (3)$$

Constants K' and n' are determined from a logarithmic plot of $D\Delta P/4L$ vs. $8V/D$ (or $32q/\pi D^3$) based on data taken with an extrusion rheometer, where n' is the slope and K' the value of $D\Delta P/4L$ at an $8V/D$ of unity. This is a general correlation and it does not make any difference what the rheological properties of the fluid are, so long as they are not time-dependent.

For Newtonian fluids where n' is unity, $N_{Re,M}$ reduces to the conventional one of $N_{Re} = DV\rho/\mu$ where $\mu = g_c K'$.

Recommended design procedure involves establishing a logarithmic plot of $D\Delta P/4L$ vs. $8V/D$ and determining the constants K' and n'. If the data do not fit a straight line, point values of K' and n' can be used as determined from tangents at desired points. Then, the modified Reynolds number is calculated, and the friction factor read off the usual friction factor vs. Reynolds number chart. Pressure drop is calculated from Eq. (2). This obviously involves a long trial-and-error calculation to get optimum pipe size.

Other investigators have used the Eyring-Powell rheological equation

$$\tau = \mu' \frac{dv}{dr} + \frac{1}{B}\sinh^{-1}\left(\frac{dv/dr}{A}\right) \qquad (4)$$

which contains three constants μ', A and B for flow in the laminar region.[8] This has the disadvantage of considerable complexity, and is limited only to those materials that adhere strictly to the equation. It has been suggested that this equation does not fit the shear-stress and shear-rate data as well as does the power law Eq. (1); and Eq. (4) should not be used where extrapolations of data are required.[7]

Nomenclature

A	Constant in Eq. (4).
B	Constant in Eq. (4).
c'	Constant in Eq. (10).
D	Pipe or tube diameter, ft.
$D\Delta P/4L$	Shear stress at the wall of a pipe or tube, lb./sq. ft.
f	Fanning friction factor (dimensionless), $(D\Delta P/4L)/(\rho V^2/2g_c)$.
g_c	Gravitational constant, 32.2 (lb.$_m$/lb.$_f$) (ft./sec.)/sec.
K	Fluid consistency index defined by Eq. (1).
K'	Fluid consistency index.
L	Pipe or tube length, ft.
n	Non-Newtonian rheological constant defined by Eq. (1).
n'	Non-Newtonian rheological constant.
N_{Re}	Conventional Reynolds number (dimensionless), $DV\rho/\mu$.
$N_{Re,H}$	Reynolds number (dimensionless) used by Hedstrom for Bingham plastic fluids, $DV\rho/\mu_p$.
$N_{Re,M}$	Reynolds number (dimensionless) used by Metzner and Reed.
$N_{Re,S}$	Reynolds number (dimensionless) used by Shaver, defined by Eq. (7).
$N_{Re,W}$	Reynolds number (dimensionless) used by Weltmann, defined by Eq. (5).
ΔP	Pressure drop, lb./sq. ft.

Reynolds Number Used for Non-Newtonians

Weltmann has presented an elaborate correlation for non-Newtonian fluids, based on the conventional friction-factor diagram, with the Reynolds number defined as:[16, 17, 18, 19]

$$N_{Re,W} = \frac{DV\rho}{\text{"viscosity"}} \qquad (5)$$

where "viscosity" is the Newtonian viscosity μ for Newtonian fluids, the plastic viscosity μ_p for a Bingham plastic, and the apparent viscosity μ_a measured for the flow conditions in the pipeline for pseudoplastic or dilatant materials.

Three different equations relate friction factor to the Reynolds number for Newtonian fluids, Bingham materials, and pseudoplastic and dilatant materials. The final correlation consists of two families of curves (one for Bingham materials and one for pseudoplastic fluids) each with its own parameter.

For pseudoplastic materials, the parameter is $1/n$, while for Bingham materials it is the plasticity number $\tau_y D/\mu_p V$, where τ_y is yield stress and μ_p is plastic viscosity as defined by the equation

$$\tau = \tau_y + \mu_p(dv/dr) \qquad (6)$$

This method for Bingham materials is very similar

$\Delta P/L$	Pressure gradient, (lb./sq. ft.)/ft. pipe.
Δp	Pressure drop, psi.
q	Flow rate, cu. ft./sec.
Q	Flow rate, gpm.
r	Radial or linear distance, ft.
v	Local velocity at r, ft./sec.
dv/dr	Local velocity gradient or rate of shear in pipeline or in a rotational viscometer, sec.$^{-1}$
$(dv/dr)_w$	Shear rate at the wall of a pipe or tube, sec.$^{-1}$
V	Mean linear velocity, ft./sec.
$8V/D$	Shear rate of a Newtonian fluid at the wall of a pipe (laminar flow), or flow function for non-Newtonian fluids, sec.$^{-1}$
ρ	Density, lb./cu. ft.
ρ_s	Solid density, lb./cu. ft.
τ	Shear stress, lb./sq. ft.
τ_w	Shear stress at the wall of pipe or tube, equal to $D\Delta P/4L$, lb./sq. ft.
τ_y	Yield stress of a Bingham plastic fluid, lb./sq. ft.
μ	Viscosity of a Newtonian fluid, lb./(sec.) (ft.), equal to $g_c\tau/(dv/dr)$.
μ_a	Apparent viscosity of a non-Newtonian fluid, lb./(sec.) (ft.) equal to $g_c\ (D\Delta P/4L)/(8V/D)$.
μ_p	Viscosity of a Bingham plastic fluid, lb./sec. ft.
μ'	Constant in Eq. (4).
δ	Ratio of $g_c\ (D\Delta P/4L)/(8V/D)$.
ϕ, ϕ'	Indicators of unspecified functional relationships.

to Hedstrom's friction factor vs. Reynolds number chart where the parameter is the Hedstrom number,[5] $\tau_y\ p\ D^2/\mu_p^2$. In both Weltmann's and Hedstrom's charts, flow remains laminar for progressively higher Reynolds numbers as the numerical value of the parameters increases.

Other work on Bingham materials has been summarized by Metzner.[7] In the special case of pseudoplastic fluids obeying the power law where $n = n'$, Weltmann's Reynolds number[8] differs from the Metzner-Reed number by a factor of $(3n + 1)/4n$. It is this difference that makes the Weltmann Reynolds number chart have a family of curves for various values of n in the laminar region.

Another Reynolds number for use with the usual friction factor of Eq. (2), in the laminar region, has been suggested by Shaver and Merrill for power-law fluids.[14]

$$N_{ReS} = \frac{D^n V^{2-n} \rho}{g_c K} \left(\frac{8}{(6 + 2/n)^n} \right) \tag{7}$$

This reduces to the Metzner-Reed Reynolds number of Eq. (3) by using the relation between K and K' given by Metzner.

$$K' = K \left(\frac{3n + 1}{4n} \right)^n \tag{8}$$

New Methods Avoid Difficulties

All of the above methods call for determining either a flow-diagram ($D\Delta P/4L$ — $8V/D$) plot or a shear-diagram (τ — dv/dr) plot. These relationships are not something that can be predicted. Viscometric data must be taken for each non-Newtonian fluid of interest.

In the new method for pipeline scaleup presented here, we determine a flow diagram and go one brief step past this to get a complete set of pipe-flow curves (Δp — gpm. plots) for various pipe sizes. This method stems directly from the work of Alves and co-workers, who obtained plots of $8q/\pi D^3$ vs $D\Delta P/4L$. They recommend pipeline scaleup directly from such a plot for any flow rate and pipe length, by assuming a pipe diameter and calculating the pressure drop or vice-versa.

Actually, calculation of the diameter for a given flow and pressure drop is a tedious trial-and-error procedure, since diameter appears in both $D\Delta P/4L$ and $8q/\pi D^3$. The term $8q/\pi D^3$ was chosen by these workers since it appears in the Rabinowitsch-Mooney equation that they used for calculating the shear-rate at the wall of the pipe:[10, 12]

$$(dv/dr)_w = 3(8q/\pi D^3) + (D\ \Delta P/4L) \frac{d(8q/\pi D^3)}{d(D\ \Delta P/4L)} \tag{9}$$

This equation contains the two terms $8q/\pi D^3$ and $D\Delta P/4L$, and the derivative $d\ (8q/\pi D^3)/d\ (D\Delta P/4L)$ is the slope of the arithmetic plot of $8q/\pi D^3$ vs. $D\Delta P/4L$. Severs and Austin simplified the Rabinowitsch-Mooney Eq. (9) to the following[13]

$$(dv/dr)_w = \frac{(c' + 3)}{4} \left(\frac{32q}{\pi D^3} \right) \tag{10}$$

where c' equals $d\ ln\ (32q/\pi D^3)/d\ ln\ (D\Delta P/4L)$.

Noting that the bulk velocity V is equal to $4q/\pi D^2$, Metzner and Reed rearranged the equation to[9]

$$\left(\frac{dv}{dr} \right)_w = \frac{3}{4} \left(\frac{8V}{D} \right) + \frac{1}{4} \left(\frac{8V}{D} \right) \frac{d\ ln\ (8V/D)}{d\ ln\ (D\Delta P/4L)} \tag{11}$$

$$= \frac{3n' + 1}{4n'} \left(\frac{8V}{D} \right)$$

where $1/n'$ is the slope $d\ ln(8V/D)/d\ ln(D\Delta P/4L)$. But if the data are plotted with $D\Delta P/4L$ as the ordinate rather than the abscissa, n' represents the slope. We prefer $D\Delta P/4L$ as the ordinate even though, when working with an extrusion rheometer where only pressure is varied (for any tube diameter and length), it should be the abscissa. In pipeline tests, it is actually flow that varies (with a pump), while in most rotational viscometers, the rate of shear (speed of rotation) is varied. But there is a more-important reason for having $D\Delta P/4L$ as the ordinate: $g_c\ (D\Delta P/4L)/(8V/D)$ has units of viscosity. (The g_c is necessary to convert pressure drop from engineering units of lb./sq. ft. to absolute units of lb./ft.-sec^2., based on mass rather than force.)

Data Fall on One Curve

Shear stress τ_w at the wall of a circular pipe is represented quite simply by $D\Delta P/4L$.

This relationship was first developed by G. G. Stokes in 1851.[11] It may be derived easily by balancing the driving force of the fluid $\pi D^2 \Delta P/4$, along with the viscous resistance τ per unit area, acting on the sides of a cylinder of area πDL with a total force of $\pi DL\tau$.

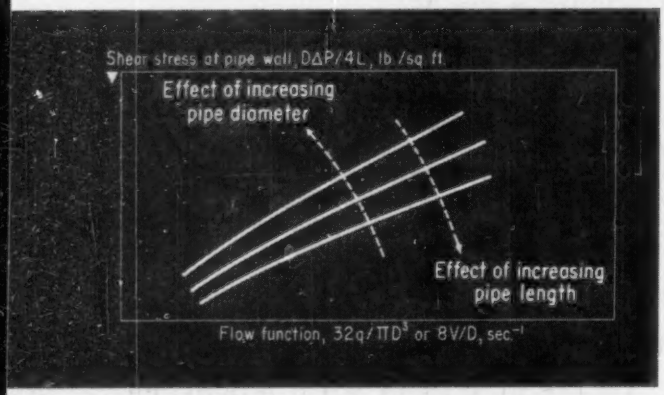
Eq. (11) gives the relationship for rate of shear at the pipe wall. It is known that the shear stress at the wall of a pipe is some function of the shear rate. Therefore, we may write

$$\tau_w = \frac{D\,\Delta P}{4L} = \phi'\left(\frac{dv}{dr}\right) = \phi'\left(\frac{3n'+1}{4n'}\right)\left(\frac{8V}{D}\right) \quad (12)$$

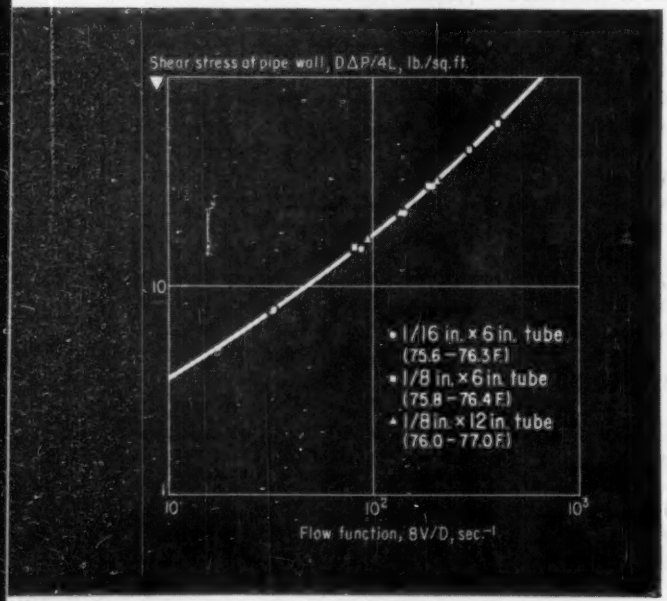
$$\frac{D\,\Delta P}{4L} = \phi\,\frac{8V}{D} \quad (13)$$

Thus, regardless of the true mathematical relationship between $D\Delta P/4L$ and $8V/D$, a plot of different values of the two terms will fall on the same curve irrespective of pipe size, pipe diameter, or flow rate, if flow is laminar. This is an established experimental fact for all fluids that are not time-dependent (thixotropic). Therefore, a plot of various values of the two terms produces a single curve based on a rigorous analysis of the fluid dynamics in the pipe. This, however, is based on the one implicit assumption that there is no slip at the wall.

Thixotropic fluids can't be handled by new method; data are not on one curve—Fig. 1


Shear stress at pipe wall, DΔP/4L, lb./sq. ft.
Effect of increasing pipe diameter
Effect of increasing pipe length
Flow function, 32q/πD³ or 8V/D, sec.⁻¹

Flow correlation for 56.8% black pigment dispersion in castor oil—Fig. 2


Shear stress at pipe wall, DΔP/4L, lb./sq. ft.
10
1
10
10²
10³
• 1/16 in. × 6 in. tube (75.6 – 76.3 F.)
• 1/8 in. × 6 in. tube (75.8 – 76.4 F.)
▲ 1/8 in. × 12 in. tube (76.0 – 77.0 F.)
Flow function, 8V/D, sec.⁻¹

It is interesting to note that if we divide $g_c D\Delta P/4L$ by $8V/D$ and let this ratio equal say δ, we can rearrange this in the form

$$\delta = \frac{g_c D\,\Delta P/4L}{8V/D} \quad (14)$$

$$\Delta P = 32\delta LV/D^2 g_c \quad (15)$$

and if we define δ as μ_a, we have a form identical with the familiar Poiseuille equation for Newtonian fluids

$$\Delta P = 32\mu_a LV/g_c D^2 \quad (9I)$$

For a Newtonian fluid, $g_c(D\Delta P/4L)/(8V/D)$ actually does represent the viscosity. Since Alves et al. used $8q/\pi D^3$, which is equal to $2V/D$ for the velocity term, their plots do not yield this relationship unless we define δ equal to $4\mu_a$. Eqs. (14-16) bring out the deficiency of the Poiseuille form of equation for other than Newtonian fluids. Since with any non-Newtonian fluid δ varies for each and every value of $8V/D$, there is no real significance to the relationship, for it is actually no more than the ratio of the two variables. In the special case of Newtonian fluids, δ is a constant at all values of $8V/D$.

With Newtonian fluids, the expression $8V/D$ is equal to the shear rate at the pipe wall $(dv/dr)_w$ since the derivative in Eq. (11) is unity for all Newtonian fluids. Therefore, the viscosity μ for Newtonian fluids may be expressed by Eq. (14) as well as by $g_c\tau/(dv/dr)$, a relationship usually determined with a rotational viscometer.

Since Newtonian fluids are actually only special cases of all fluids, it should now be apparent why there is no longer any theoretical basis for talking about "apparent viscosities" used in Poiseuille's equation for non-Newtonian fluids.[3] The term $8V/D$ may best be called a "flow function," since it is not the rate of shear for non-Newtonians. Therefore a plot of $D\Delta P/4L$ vs. $8V/D$ or $8q/\pi D^3$ is not a "shear diagram" as has been suggested.[3] We will designate it as a "flow diagram." For Newtonian fluids, Poiseuille's equation applies only in the laminar region, because in the turbulent region, viscosity can no longer be expressed by the ratio of $(D\Delta P/4L)/(8V/D)$.

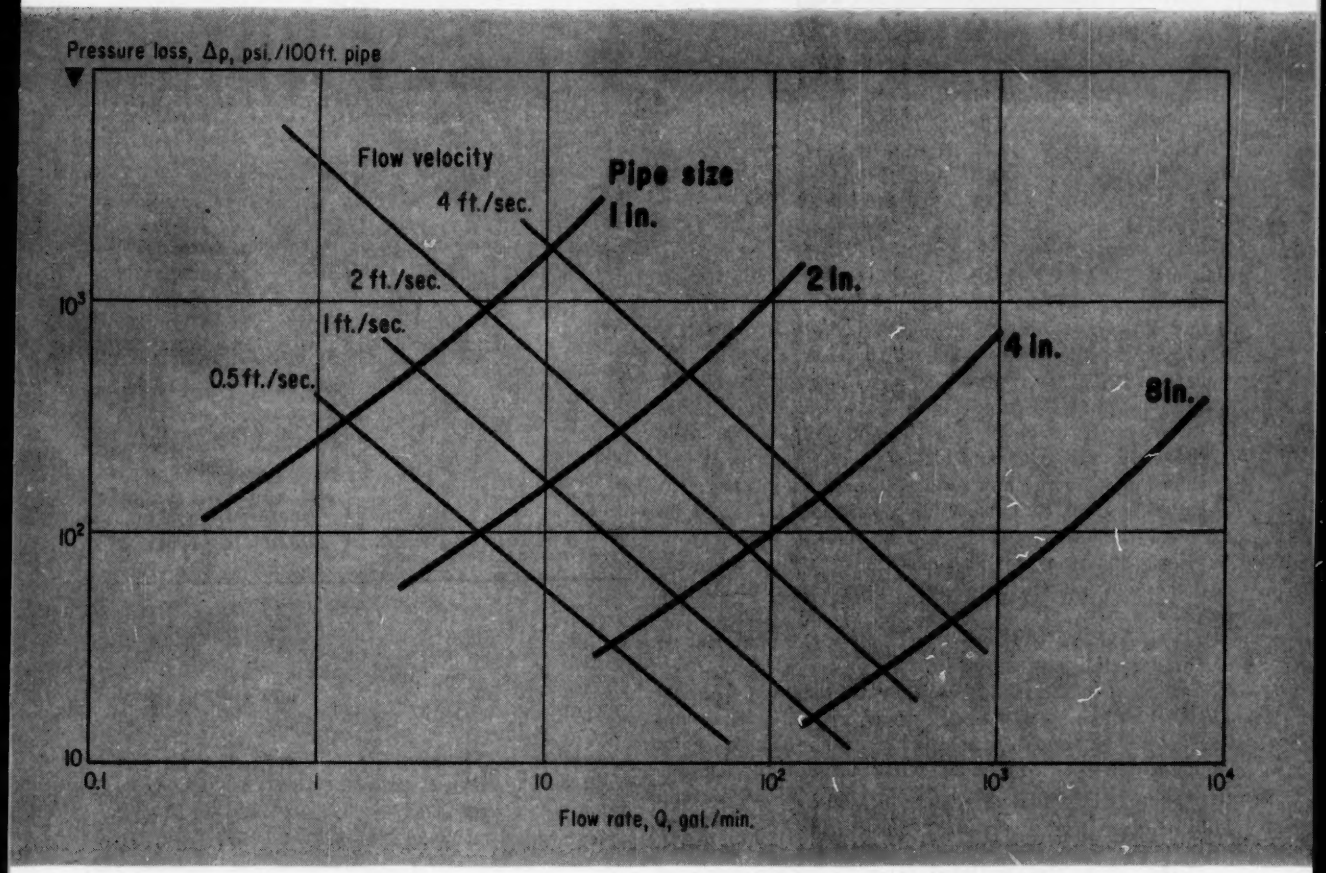
Getting Data for Curve

Data for constructing plots of $D\Delta P/4L$ vs. $8V/D$ are obtained very easily with an extrusion rheometer.

This instrument consists of a reservoir with a small bore tube fixed to the bottom. The reservoir is filled with fluid to be tested, and gas pressure is introduced above the fluid. A sample of the material collects in a cup. Time necessary to collect the sample is measured.

Weight of the sample, time, and density of the material, are the only measurements required of the fluid.

Pipe-flow chart shows effect of flow rates on pressure drop for 56.8% dispersion—Fig. 3



It is not necessary to calculate velocity for the term $8V/D$, since by substituting $4q/\pi D^2$ for V we get

$$8V/D = 32q/\pi D^3 \qquad (17)$$

It should be remembered that q is the volume per unit time and unit volume forced through the tube is constant, so what is measured is the time necessary for the constant q to pass through the tube.

Doesn't Work for Time-Dependent Fluids

Values of q are measured for different values of ΔP, and the terms $D\Delta P/4L$ and $32q/\pi D^3$ are calculated from the instrument constants D and L, expressing the terms in consistent units, such as ft. for D and L, cu. ft./sec. for q, and lb./sq. ft. for ΔP.

Two tube diameters and two different lengths of the same diameter tube should be used to assure that the fluid is not a time-dependent thixotropic or rheopectic material. If the fluid is time-dependent, different curves will be obtained for each length and diameter. If the material is thixotropic, the effects of different diameters and lengths are shown in Fig. 1. With a thixotropic fluid, the shear-stress decreases with time at a constant rate of shear. For a rheopectic material, the reverse is true for different pipe diameters and lengths, since shear stress increases with time at a constant rate of shear. If either of these materials is present, this proposed scaleup treatment cannot be used.

In some cases, even when the fluid is known to be independent of time, data for different tube diameters may fall on different curves. This sometimes happens with slurries, and indicates anomalous flow behavior at the tube wall.[4, 20, 21] Such data cannot be used for scaleup.

Calculate for Various Pipe Sizes

With normal time-independent non-Newtonian fluids, all of the data from different pipe diameters and lengths fall on a single $D\Delta P/4L - 32q/\pi D^3$ curve (Fig. 2). While this does correlate the data very well, a single-curve correlation is not as useful as multiple curves representing different pipe sizes. We, therefore, take the smooth curve of the correlated data and tabulate various values of the two variables. Then, nominal pipe sizes are taken. The values of the con-

Calculate curve constants—Table I

Nominal Pipe Size, In.	D, In.	$aD/4L$	$b32/\pi D^3$
1	1.05	0.0315	33.9
2	2.07	0.0621	4.43
4	4.03	0.121	0.60
8	8.07	0.242	0.0747

stants $aD/4L$ (with L equal 100 ft. and a conversion factor a to convert ΔP from lb./sq. ft. to lb./sq. in.) and $b32/\pi D^3$ (with a conversion factor b to convert q to gal./min.) are calculated. With these constants, the values of Δp (psi.) and Q (gpm.) are calculated for each pipe size. Since this is done in tabular form, these can be run out very easily and quickly. And once the constants $aD/4L$ and $b32/\pi D^3$ have been calculated, they are good for any fluid. An example of the constants is given in Table I for pipes from 1 in. to 8 in.

Let's illustrate the method of scaleup with a very viscous plastic material consisting of a black pigment dispersion (56.8% by weight) in a liquid plasticizer (castor oil).

The $D\Delta P/4L - 32q/\pi D^3$ values for this material do not describe a straight line on either a logarithmic or an arithmetic plot (Fig. 2) so it does not resemble either of the classic fluids (pseudoplastic or Bingham plastic). But since our method of scaleup is universally applicable to all time-independent fluids in the laminar region, there is no problem. Values of $D\Delta P/4L$ and $32q/\pi D^3$ are taken from the smooth curve at three or four points (or possibly more depending on the shape of the curve) and tabulated. Then, using the values of the constants $aD/4L$ and $b32/\pi D^3$ for different pipe sizes, the Δp per 100 ft. and the flow Q are calculated as in Table II.

Values of Δp and Q are plotted logarithmically to give accuracy to the lower values in reading the chart (Fig. 3). When Δp and Q data for different pipe sizes are plotted in this manner, the data are automatically extended to the maximum and minimum flow limits for each pipe size, if the maximum and minimum values of $D\Delta P/4L$ and $32q/\pi D^3$ have been used in the tabulation. Linear flow velocities can be easily added to such a chart.

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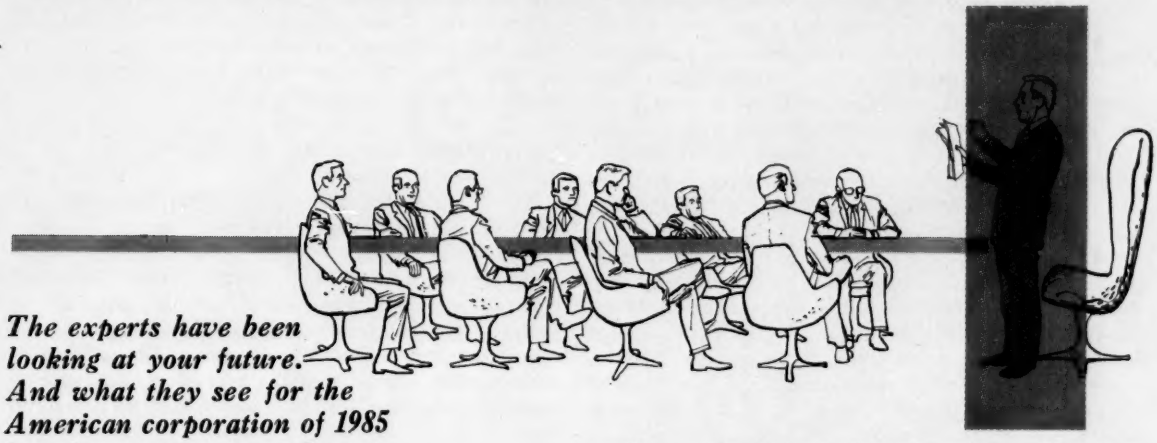
Meet the Author

RICHARD L. BOWEN, JR., *is president and treasurer of Coated Textile Mills, Inc., Pawtucket, R. I. Getting his A.B. in chemistry at Princeton in 1941, he later attended M.I.T., earning his M.S. in 1943 and ScD. in 1949, both in chemical engineering. From 1944-48 he was a design and construction engineer with Aramco in Saudi Arabia. He is the author of numerous articles on power transmission, and wrote an eight-page feature on "Variable Speed for Process Control" that appeared in Chem. Eng., July 1955. He also holds patents on devices relating to mechanical and hydraulic power transmission. He is a member of the AIChE, ACS, ASME, and the Instrument Society of America.*

Flow, pressure drop calculated for pipe sizes—Table II

		1-In. Pipe		2-In. Pipe		4-In. Pipe	
		Δp/100 ft.	Q, Gal./Min.	Δp/100 ft.	Q, Gal./Min.	Δp/100 ft.	Q, Gal./Min.
$D\Delta P/4L$	$32q/\pi D^3$	$\left(\frac{D\Delta P/4L}{0.0315}\right)$	$\left(\frac{32q/\pi D^3}{33.9}\right)$	$\left(\frac{D\Delta P/4L}{0.0621}\right)$	$\left(\frac{32q/\pi D^3}{4.43}\right)$	$\left(\frac{D\Delta P/4L}{0.121}\right)$	$\left(\frac{32q/\pi D^3}{0.60}\right)$
3.6	10.0	114	0.30	58.0	2.26	29.8	16.7
7.2	30.0	228	0.89	116	6.77	59.5	50
17.5	100	555	2.95	282	22.6	145	167
45	300	1430	8.85	725	67.7	372	500
90	600	2860	17.7	1450	135	744	1000

Will You Be Able to Run a 1985 Firm?



The experts have been looking at your future. And what they see for the American corporation of 1985 has five management lessons for you: in computers, social responsibility, disclosure, power, engineering ethics.

"The prevailing image of the corporation manager," said Richard Merton of Columbia University, last year, "is of a creature garbed in a distinctive gray-flannel uniform, member of a tribe of organization men who are aiming to join the power elite while competing for promotion in the executive suites of crystal palaces."

Although the books from which Merton drew his composite corporate manager were written to shock, a great many other things said at Carnegie Tech last year by serious management authorities may seem more shocking to you.* But if you're interested in management as a career goal, you'll want to know what kind of world you may have to operate in.

Like many other educational institutions these days, the ten-year-old graduate school of industrial administration at Carnegie Tech paused on its birthday, looked to the past, looked to the future. And, as M.I.T. had done during its centennial celebration (*Chem. Eng.*, May 29, p. 102), the Carnegie Tech business school invited some prominent scholars and practitioners to focus and highlight the important.

To look 25 years into the future takes powerful insight. Yet, this is what Tech asked of its symposium speakers.

Here is the problem: the corporation, as an economic institution, has evolved to its central role of power in the economy in a fairly brief period. Within the corporation, managers have had to make decisions that in sum essentially dictate the nation's rate of investment and therefore its growth. Managers of the 1985 corporation, now training in the universities and on-the-job, will have to face even greater complexities of onrushing technological, economic, political and social change.

And what did the intellectuals and men of affairs turn up at Tech? A good many things worth pondering. But if you're interested in the five main points that will probably affect the manager's job, here briefly is what they are:

- Computers may eliminate much of "middle" management, may modify the task of top management.
- Shareholders may, by tighter control of cash flow, limit the "social responsibility" of the manager.
- Corporation-government relationships will recognize changing corporate power.
- Multinational interests will affect public knowledg of the corporation's affairs.
- Engineering's ethics may change and be changed.

Automation-Displaced Managers?

Samuel Butler wrote in "Erewhon" that "we are misled by considering any complicated machine as a single thing." Vague echoes of that thought interposed the lines of Herbert Simon's paper in the symposium. Simon, an economist who has turned in recent years to probing the most-advanced problems of computers, questioned whether the 1985 corporation will be managed by machines.

Holding that production and office automation of today reveal something of the nature of management problems in the future, Simon cited two reasons for starting his analysis with them. The business firm of 1985 will be a complex man-machine system that is bound to color executive action. Too, the factors of automation that have affected blue-collar and clerical workers (and moved the Dept. of Labor to set up an Office of Automation and Manpower) may also affect managers.

* "Management and Corporations 1985," McGraw-Hill Book Co., New York, 1960.

Given full employment, and a mix of intelligence and ability like today's, Simon says the occupational profile will change according to the economic doctrine of comparative change. There will be a higher percentage of jobs in fields in which machines have the least comparative advantage over people, a lower percentage of jobs where machines have greatest comparative advantage. Given a consistent quality of decision, a computer that makes investment decisions 100 times faster than executives, and settles grievances 10 times faster, will handle investment; the men will dispose of grievances.

Skipping over details of the changes in information processing (Simon describes them neatly), what are the ramifications for the manager in 1985? If you will grant that the middle-management level is largely occupied with solution of well-structured problems, rather than the ill-structured problems of top managers, then the middle-level executive will be displaced by machines. And in a real sense, the executive's job will be one of planning, with much less emphasis on putting out fires.

Simon concludes that management will lose much of its attractiveness as a creative outlet, as more and more decisions become automated. (Of course, the engineering of these complex man-machine systems may become more creative.) Work and production will no longer be primary goals of men, but on the other hand, the per capita capacity to produce will rise by automation to eradicate human want.

A Decline of "Social Responsibility"?

Implied in Simon's argument is a belief that the managers remaining in the corporation may need to take a more-social, more-psychological, more-philosophical view of the world around them. But another participant in the Carnegie Tech symposium thought otherwise.

Asking in whose interest the corporation should and would be run in 1985, Friederich Hayek asserted "the tendency to allow and even to impel corporations to use their resources for specific ends other than those of long-run maximization of return on [their] capital tends to confer upon them undesirable and socially dangerous powers." In other words, it's human enough for the public at large, or even for most shareholders, to welcome corporate expenditures for education, charity and politics. And even today, the government encourages part of these expenditures by its tax policies, for example.

The consequences of these "social" actions by managers, Hayek argues, run quite opposite to the public interest. Dangerous and arbitrary powers accrue to these corporations because of "the capacity to direct the energy and resources of others to the service of values which those others do not share." Springing from control of the largest share of the economy's capital, corporate power would be socially dangerous if the wielders of that power—the corporation's managers—could spend the capital according to their own lights, unfettered by those who supplied it.

Another result follows. If it were widely accepted that managers could and should spend corporate money for social projects, then the government would have all the excuse it would need to control and direct the managers—to protect the public interest.

Hayek sees one solution: redistribute some of the managerial power to shareholders. He suggests that if the shareholder were to indicate annually how much of his share of the corporate profits were to be paid him, and how much plowed back into the firm, the manager would have no choice but try to maximize profit per unit of invested capital.

Corporations, Nation and World

Adolf Berle, Jr., and David Lilienthal—both successful in business and government—were also symposium speakers. Their perception of the corporation-government relationship of the future indicated, counter to Hayek, closer and more-cooperative action.

Berle, who has for years given his attention to the acquisition and application of capital by our largest corporations, argued that the best countermeasure to business-cycle dips is for business to keep up its capital expansion.

For example, in the recession of 1957-58, Arthur Burns, who had been Eisenhower's chief economic adviser, called a meeting of top managers of some of the country's largest firms. Its purpose was to persuade them not to shelve plans for new spending and, according to Berle, the meeting worked. Far speedier than government spending, the private capital "proved an important contributing force toward preventing a substantial depression."

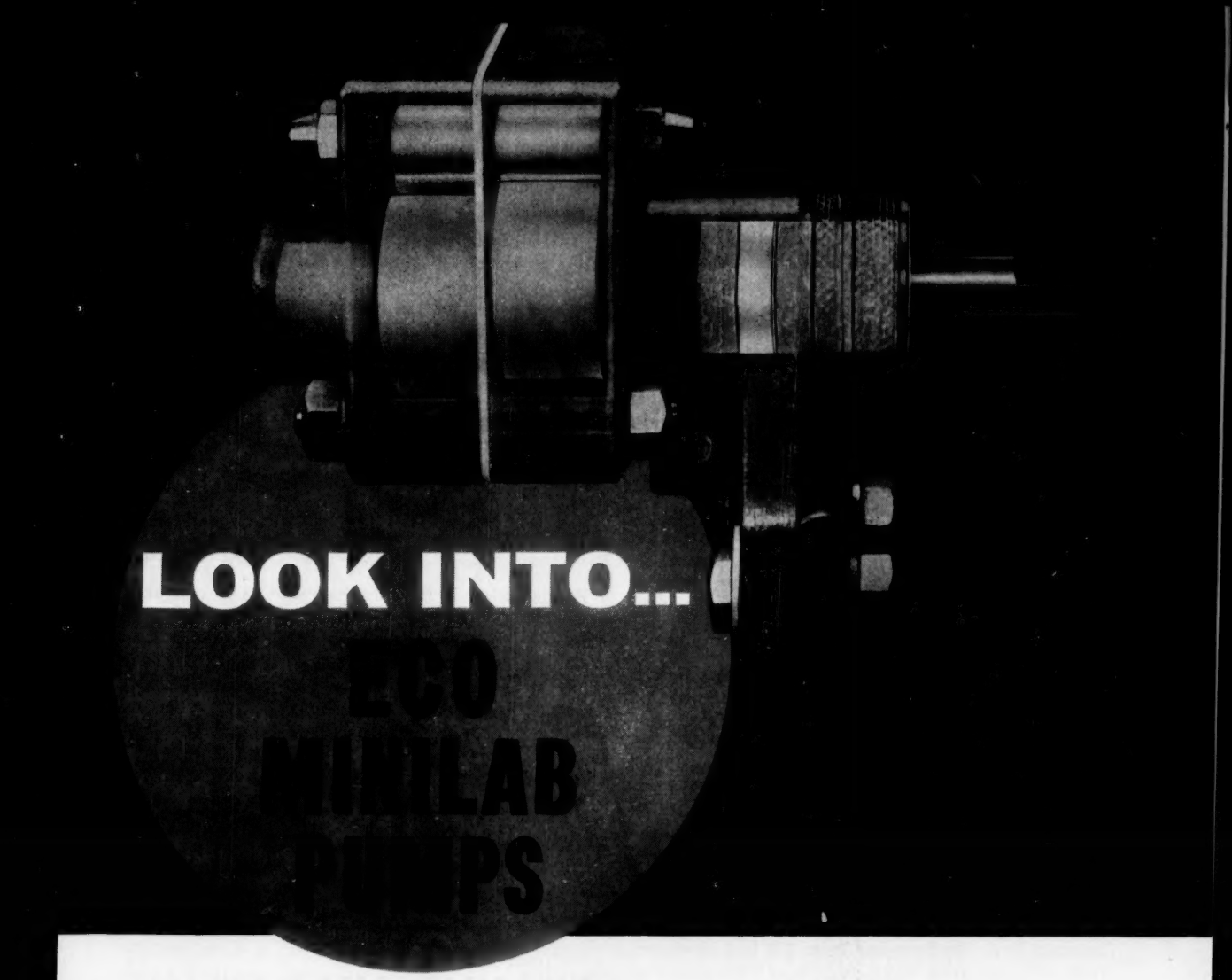
Two conclusions were drawn from this analysis: we will continue to need this concentrated power of private corporate capital, and somehow—perhaps through a nonpolitical council of corporate chief officers—its use will have to be institutionalized.

Based on his experiences of applying private capital to foreign development projects, Lilienthal offered many valuable tips for the corporation that sees good future prospects abroad. One tip is to expect that others will find out more about what you are doing. The price of doing business in another land is greater exposure of corporate affairs to its government, therefore to the public. But some benefit can accrue, too; the principle of full-disclosure assures self-scrutiny and self-correction.

There's too little space here to go into Robert Hutchins' brief that education can make 1985 whatever we want it to be. Rather ponder the implications of what he said about modern technology:

"The process called in some engineering circles 'optimization' leads not merely to steady improvement in the methods of production. It induces a new state of mind. We think no more of what things are, but only of the uses to which they can be put. We think of results and not of ends. If we think of human beings . . . we think of them as Man, an abstraction that will somehow ultimately benefit through the optimization that throws real, living men out of work."

The whole symposium was loaded with such challenge; it's a good primer for your future.



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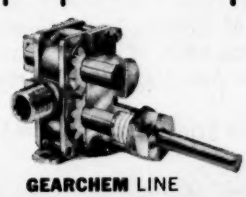

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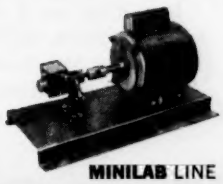

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IS THE BACHELOR'S A TERMINAL DEGREE FOR CHEMICAL ENGINEERS?

A recent study by Elmer West of the American Council on Education (*J. Eng. Ed.*, 51, 545, 1961) offers little consolation to chemical engineers who feel that graduate studies are important to their profession.

Citing the academic decade 1949-50 to 1958-59, West has compared the number of new engineering degrees by field at three degree levels. Fields included in the comparisons are aeronautical, chemical, civil, electrical, industrial, mechanical, metallurgical and "all other."

Although *CE* has noted the phenomenon of declining enrollments and its effect on degree production (*Chem. Eng.*, Mar. 6, p. 58), the trends in specialization among various disciplines are boldly asserted in the data compiled by West. At B.S. level, for example, chemical engineers maintained their share throughout the decade: from 9.2% of all degrees in 1949-50 to 8.9% in 1958-59.

In percentages, pretty much the same distribution among all fields occurred throughout the decade, except for aeronautical, which, though a small increment, grew from 2.7% to 4% of all B.S. engineering degrees. And electrical stood first at the end of the decade, having overtaken the mechanicals in 1956-57.

The story isn't so comforting at higher degree levels. At both master's and doctorate's levels, the proportions of aeronautical, chemical and metallurgical degrees trended downward. Masters of chemical engineering awarded dropped from 711 to 596 during the decade—from 14.6% to 8.9% of total awarded. At doctorate level, the drop was from 178 to 143—a precipitous descent from 36.2% to 20% of all engineering doctorates.

(As pointed out by *CE* previously, last year's master degrees awarded in chemical engineering climbed 18.5%, doctorates awarded rose 19% over 1958-59.)

In an electronics age, electrical engineers have gradually gained a larger share of degrees at all levels, but particularly at the highest. Perhaps students lost by chemical engineering have been gained by electrical. But it seems ominous that the only marked drop in all disciplines at the two higher degree levels happened in chemical engineering.

AMERICAN INDUSTRIAL FIRMS ARE BIG-TIME SPENDERS IN EDUCATION

Reporting on a study of industry's relationships with education, the National Assn. of Manufacturers, New York, has shown how American business stakes American education.

Based on replies of 2,186 firms of all sizes and industries, the figures reveal that greatest attention (by number of companies) goes to employment of students on a part-time basis, and special or unrestricted money grants. Least attention goes to such activities as education loan funds, fellowships, matching money grants and endowments.

But in terms of money spent, the activities that are supported by only a small part of the business community received the most support. The following table shows for 1959 what the extent of financial aid by these companies was:

Activity	No. of Firms	% of Total	Cost, $1 Million
Special or unrestricted grants	1,309	60	13.60
Scholarships	593	27	4.03
Tuition refund programs	478	22	2.87
Research grants	267	12	3.22
Loan funds	130	6	0.79
Fellowships	120	5.4	1.75
Matching gifts	76	3.4	0.82
Endowments	68	3.1	0.79

Participation by size of company is also broken down in the NAM figures and, interestingly, the financial aid seems to be allocated to those activities shown in the table in about that order, no matter what the size of the firm. For all financial aid in 1959, the small firms (1-499 employees) spent $3.7 million, medium firms (500-2,499 employees) spent $6.4 million, large firms spent $8.4 million. Firms of unknown size answering accounted for $9.4 million.

The study covers many other areas of aid to education besides financial. And it also offers tidbits on related spheres of industry's interest. For example, in 1959, 381 firms spent $837,800 in organized college visits and recruitment programs.

NSPE SALARY DATA IN FOR 1960

As it has in several past periods, the National Society of Professional Engineers has again surveyed its members for salary data in the same year that Engineers Joint Council studied income of all engineers. The latest coincident surveys covered 1960. A report of the EJC survey was given in *CE*, Mar. 20, p. 172, and early NSPE data have now been tabulated.

With information from over 40% of its membership, NSPE has found that nine out of ten of its members earn more than $7,140, three quarters of them more than $8,580 and one quarter, over $13,750. Unchanged from the 1958 survey, the upper decile has a lower salary boundary of $19,680. The median salary of all members is $10,660—up from $10,000 in 1958.

Here's how median income figures of NSPE compare with those of EJC: for 1960 entry into the profession, NSPE is $5,620, EJC is $6,300; for 1958, NSPE is $7,270, EJC is $7,125; for 1955, NSPE is $8,590, EJC is $8,100; for 1925-29, NSPE is $14,920, EJC is $12,175.

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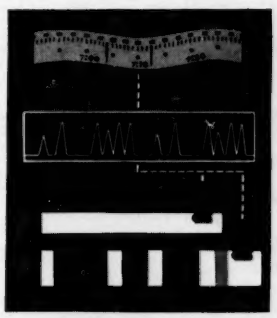

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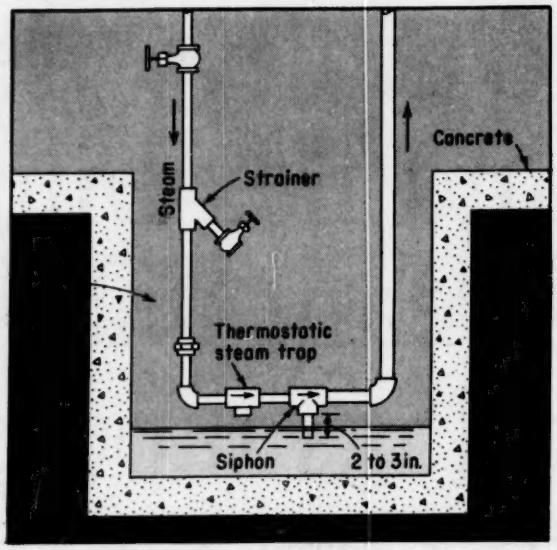


- Low initial cost and maintenance cost because of the elimination of a micro switch, float apparatus and solenoid valve.

GRAPHICAL METHOD FINDS LOGARITHMIC MEAN VALUES

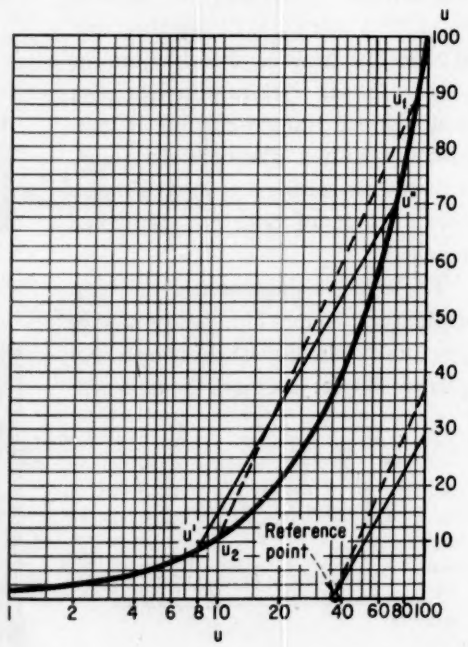
HEINE LAPIDOT
Beersheba, Israel

This article presents a graphical method for determining logarithmic mean values.

In the expression

$$u_m = \frac{u_1 - u_2}{\ln (u_1/u_2)}$$

u_m can be interpreted as the slope of the straight line passing through the points (u_1, ln u_1) and (u_2, ln u_2) of the curve representing u vs. ln u, or the slope of the tangent parallel to that straight line. Such a plot of u vs. ln u is the same as a plot of e^u vs. u, i.e.,



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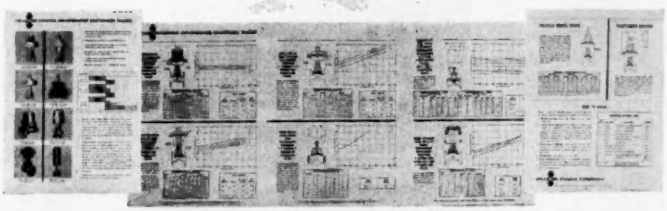

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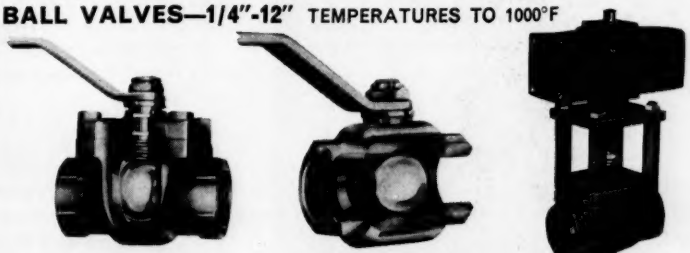

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it is an exponential curve, as shown by the diagram.

An important characteristic of exponential curves is the fact that the subtangent (the projection, on the x axis, of the segment of the tangent line between the point of tangency and the intersection with the abscissa) has a constant value. Thus, if a suitable scale is chosen, we can directly read the values of u_m on the vertical axis. The procedure is as follows:

1. Plot u vs. ln u on semilog paper with u as ordinate on the linear scale.

2. Calculate one arbitrary numerical value, say for $u_1 = 90$ and $u_2 = 10$:

$$u_m = \frac{90 - 10}{\ln (90/10)} = 36.4$$

3. Draw the secant to the curve through points u_1, u_2 as shown.

4. Mark off the length of the subtangent as follows: draw a line parallel to the secant through the point 36.4 on the right-hand ordinate.

To obtain u_m for two values (u', u'') draw a line through the reference point parallel to the secant through the two values, and read off the result on the ordinate.

For example, $u' = 8$ and $u'' = 70$. Then, $u_m = 28.6$.

Of course, this method is also useful if it is desired to find one of the extreme values when the second extreme value and the mean value are known, thus avoiding reiteration.

THEORETICAL PLATES WITH NO EQUILIBRIUM PLOT

FERDINAND RODRIGUEZ
Cornell University, Ithaca, N. Y.

The McCabe-Thiele method of stepping off ideal plates is part of every engineer's introduction to binary distillation. In the specific case where the relative volatility α of the two constituents is independent of composition, and the McCabe-Thiele assumptions are valid, a common procedure is to make an equilibrium plot for liquid-vapor composition (x,y) from the relationship

$$\frac{y}{1-y} = \alpha \frac{x}{1-x} \qquad (1)$$

Next, operating lines are drawn, based on reflux ratio R and overhead composition x_D and on boil-up ratio R_B and bottoms composition x_B

$$y_{n+1} = \frac{R}{R+1} x_n + \frac{1}{R+1} x_D \qquad (2)$$

$$y_{n+1} = \frac{R_B + 1}{R_B} x_n - \frac{x_B}{R_B} \qquad (3)$$

The two operating lines are also related by feed composition x_F. Here, q is mole fraction of vapor in the feed.

$$R_B + 1 = \frac{R(x_F - x_B) + q(x_D - x_B)}{(x_D - x_F)} \qquad (4)$$

Then, ideal plates are stepped off from point x_D to x_B.

We can get around drawing the conventional diagrams by combining nomographic solutions of Eqs. (1), (2) and (3). In Fig. 1, the lines x_n and y_{n+1} with point M represent the solution of Eq. (2) and, with point Q, the solution of Eq. (3).

Lines x_{n+1} and y_{n+1} with point E solve Eq. (1), and points M, P and Q serve Eq. (4).

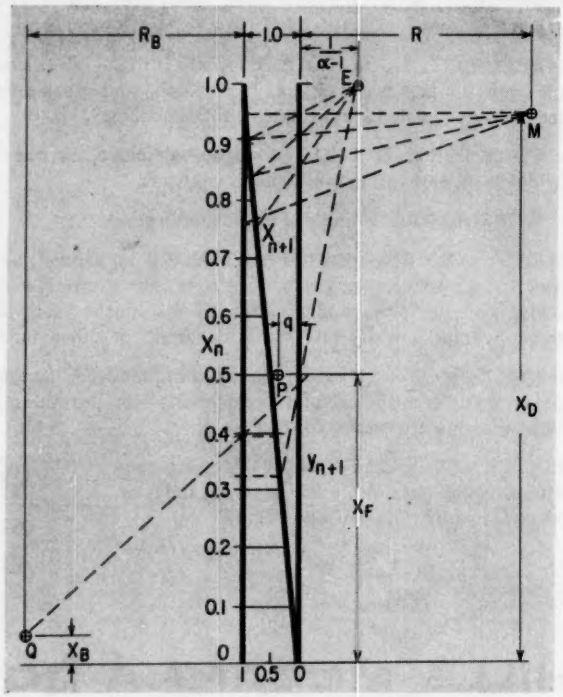
The unit horizontal distance between the x and y scales can be varied to suit the individual. Any rectangular graph paper can be used without plotting lines, curves or exotic scales. An example will illustrate this method:

Given: $x_D = 0.95$, $x_B = 0.05$, $\alpha = 2.0$ and $R = 4.0$. The feed enters with 0.40 mole fraction q as liquid and an over-all composition of $x_F = 0.5$.

Locate points:

E at $1/(\alpha - 1) = 1.0$
M at intersection of R and x_D.
P at intersection of x_F and q.

Continued on page 258



TEST YOUR CEQ

ROBERT LEMLICH

A tank of 1 cu. ft. capacity contains air at 0.3 atm. absolute pressure. The tank valve is then cracked, and air from the room is admitted until the tank pressure rises to the prevailing barometric pressure of 1 atm. Temperature of both tank and room are 80 F. at start and finish. How much heat passes through the tank walls?

Answer on page 260

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and Gage Safely and Accurately with JERGUSON MAGNETIC GAGES

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Jerguson Magnetic Gages are available in four models to fit a variety of installation needs. The float is adjusted for specific gravity and correlates pressure, temperature and specific gravity.

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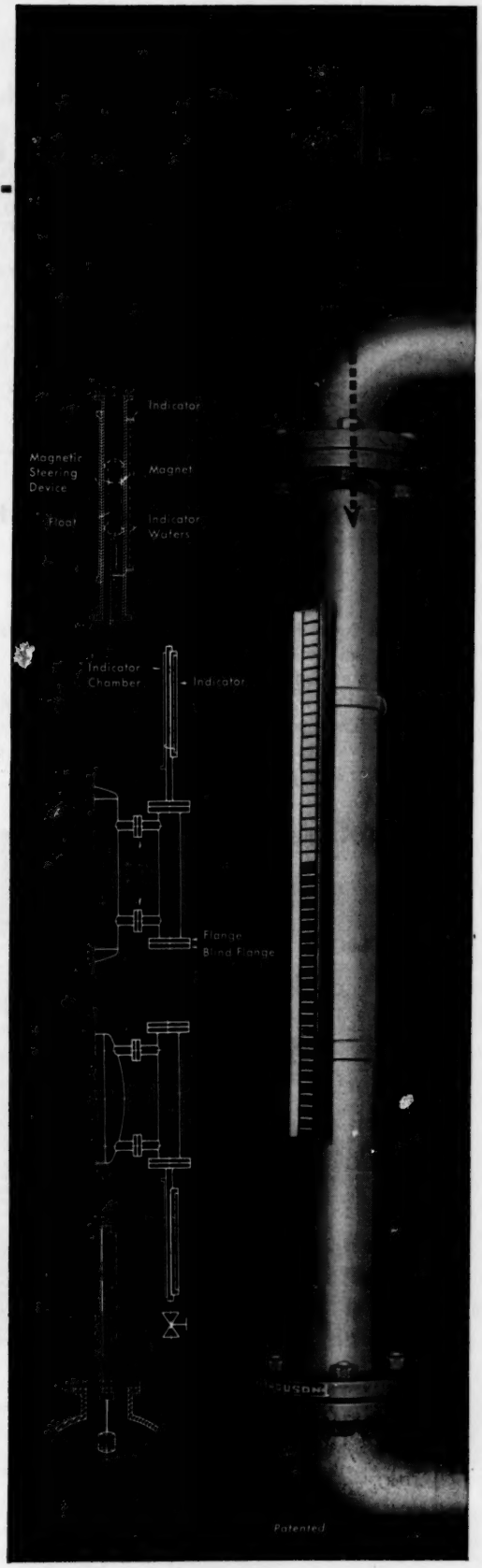


Q at intersection of line through M and P with x_B. (R_B=3.80).

Number of theoretical plates:

Plate 1: a) Connect $y_n = 0.95$ with M. Read $y_{n+1} = y_1$ (0.95).
b) Connect $y_{n+1} = y_1$ and E. Read $x_{n+1} = x_1$ (0.905).
c) Move horizontally to $x_n = x_1$.

Plate 2: a) Connect $x_n = x_1$ and M. Read y_2 (0.914).
b) Connect y_2 and E to get x_2 on x_{n+1} (0.841).
c) Move horizontally to $x_n = x_2$.

On reaching the feed plate, switch to point Q instead of M.

Plate 8: a) Connect $x_n = x_7$ (0.39) with Q. Read $y_{n+1} = y_8$ (0.48).
b) Connect $y_{n+1} = y_8$ and E. Read $x_{n+1} = x_8$ (0.32).
c) Move horizontally to $x_n = x_8$.

Continue plotting in this fashion until the bottom composition is reached.

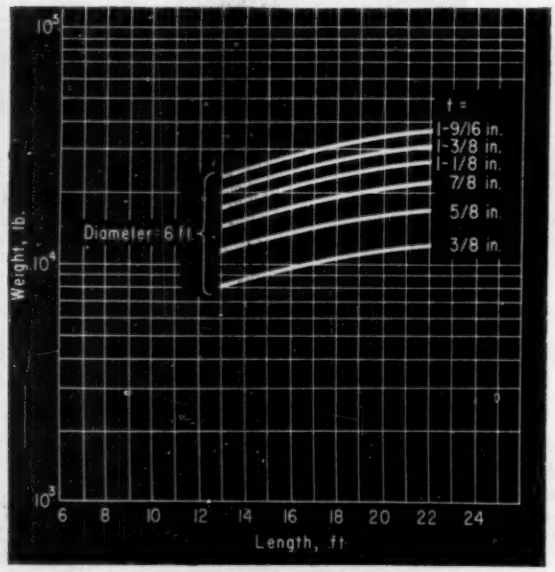
CHARTS GIVE VESSEL WEIGHT

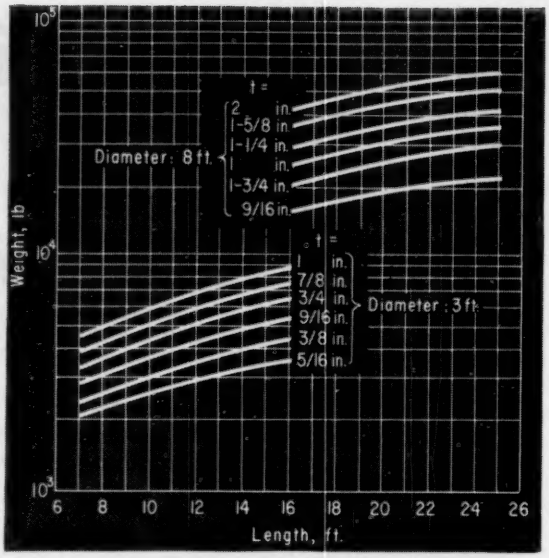
JACKSON CLING
Holland, Mich.

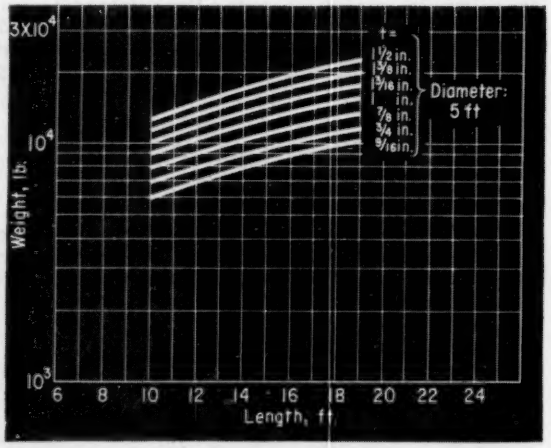
These four charts give the weight of vertical cylindrical steel process vessels.

The length given is that between tangent lines, and the weights include two dished heads, reinforcing rings, manways, nozzles and supporting rings.

These weights are approximate and are useful for estimations or checking calculations.







Correction

In the article, "One-Step Equations to Find Reboiler and Condenser Duty,"—Feb. 20, p. 164—Eq. (5) should read as follows:

$$Q_r = F[C(R+1) + (q-1)]\,\Delta H_v \qquad (5)$$

NOMOGRAPH GIVES DIFFUSION RATE IN DILUTE SOLUTIONS

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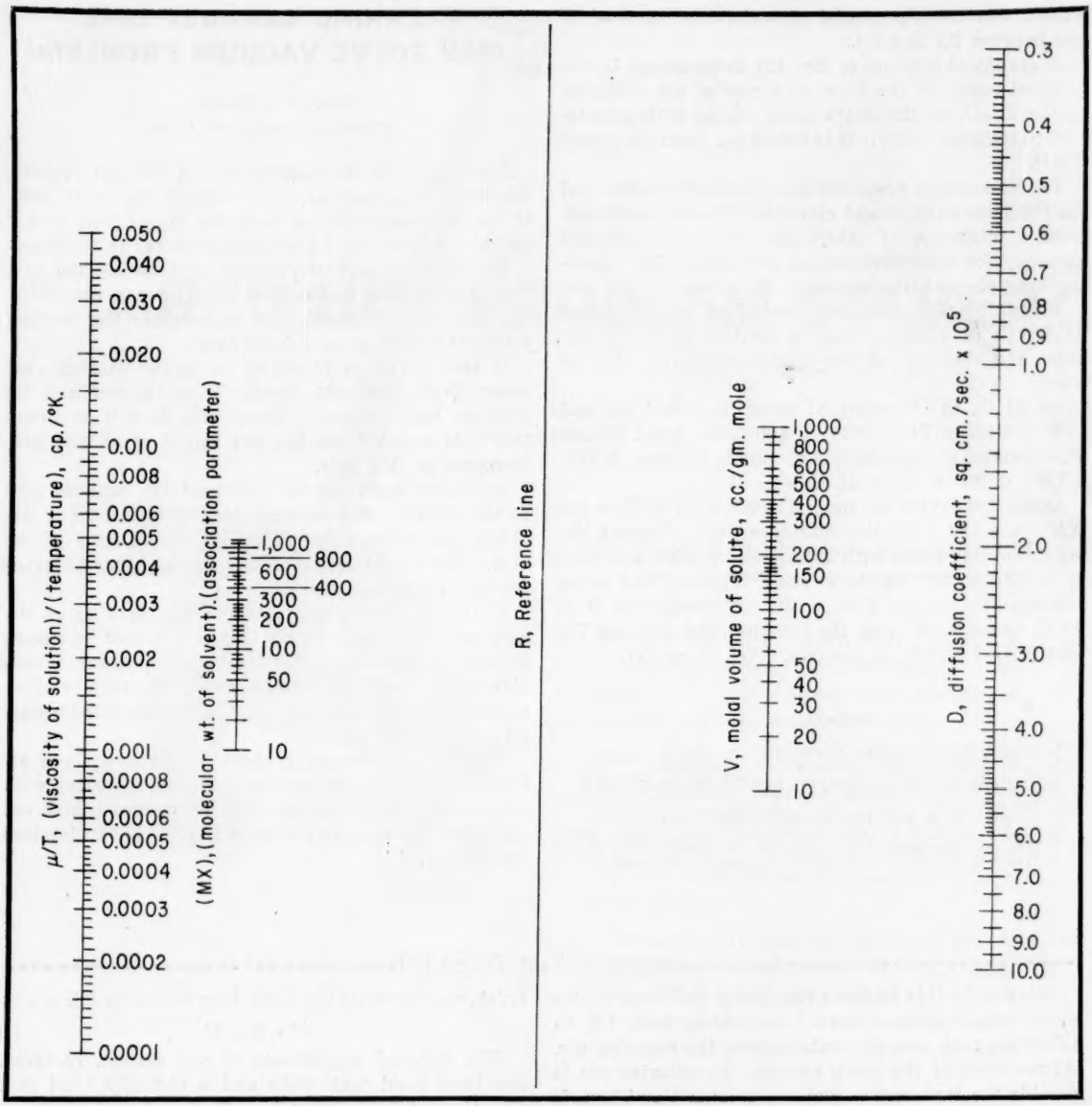
Atlas Powder Co., Wilmington, Del.

Means for predicting the diffusion coefficient in dilute solutions in the absence of measured data have received some attention in recent years. In general, two approaches have been used to develop expressions that will predict these coefficients. One approach uses the kinetic theory of gases applied to the liquid state, and the other uses an extension of Eyring and coworkers' theory of absolute rates to diffusion in liquids.

Although many equations have been proposed, the most commonly known are those of Arnold,[1] Scheibel,[2]



Thakar and Othmer[6] and Wilke.[7, 8] In addition, Olson and Walton[5] proposed a correlation based on surface tension lowering of the solvent by the solute.

The most recent correlation, based on qualitative conclusions of Eyring's theory and the Stokes-Einstein relation, is that of Wilke and Chang[8] as modified from the original work of Wilke.[7] In this correlation, the group $T/\mu D$, referred to as the diffusion factor F, is correlated in terms of the molal volume, using an association parameter. The proposed generalized equation for diffusion coefficient in dilute solutions is:

$$D = \frac{7.4 \times 10^{-8} (XM)^{0.5} T}{\mu V^{0.6}} \quad (1)$$

where,

D = diffusion coefficient of solute, sq.cm./sec.
M = molecular weight of solvent.
V = molal volume of solute at normal boiling point, cc./g.mole.
T = Temperature, °K.
X = association parameter to give effective molecular weight.
μ = viscosity of solution, cp.

The value of V, the molal volume, is calculated by the usual method of atomic volume contributions. Tables of atomic volumes are given in several references.[1, 2, 4]

The value of X, the association parameter, is introduced to define the effective molecular weight of the solvent with respect to the diffusion process. The recommended values for X in the original reference[8] are: $X = 1.0$ for nonassociated solvents and 2.6 for

water. For certain special solvents, the value of X lies between 2.6 and 1.0.

A graphical solution of Eq. (1) is presented in the original paper in the form of a plot of the diffusion factor, $T/\mu D$, vs. the solute molal volume with association parameter (XM). D is solved for from the group $T/\mu D$.

The nomograph presented here has been constructed for the same purpose and gives the diffusion coefficient with a minimum of calculation and with sufficient accuracy for most engineering purposes. The following example will illustrate.

Estimate the diffusion coefficient of mannitol ($C_6H_{14}O_6$) in a dilute aqueous solution at 70 C. Assume the viscosity of the dilute solution is that of water.

At 70 C., the viscosity of water is 0.4061 cp. and $\mu/T = 0.4061/(70 + 273) = 0.001185$. Molal volume V, calculated by the addition of atomic volumes, is 185. $(XM) = 2.6 \times 18 = 46.8$.

Connect 0.001185 on the μ/T scale with 46.8 on the XM scale and with the reference line. Connect the reference line point with 185 on the V scale and read $D = 1.86 \times 10^{-5}$ on the D scale. The solution using the equation is also 1.86×10^{-5}. The value of D at 70 C. as obtained from the International Critical Tables is 1.56×10^{-5} sq. cm./sec. (Vol. V, p. 71).

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CLEANING EXHAUST LINE MAY SOLVE VACUUM PROBLEM

KISHOR H. PAREKH
Tata Chemicals Ltd., India

Sometimes, in the operation of a vacuum process, the absolute pressure of the system begins to rise. If the pressure remains high for longer and longer periods, a check of the vacuum producer is indicated.

The check is best carried out by isolating the unit from the process so that the operator can determine the source of the leak, that is, whether the vacuum producer or the process is at fault.

If the trouble is found to be in the vacuum producer itself, the unit should be overhauled and its capacity then checked. Sometimes, it will be found that this maintenance has not helped at all and performance is still poor.

In such a case, the vacuum producer exhaust may be the culprit. Any accumulation of water, oil or liquid in the exhaust line decreases the capacity of the unit. The accumulation of this material may be gradual or it may occur rapidly.

If the buildup is gradual, periodic cleaning of the exhaust system may be all that is required to ensure good performance. If, however, buildup is rapid, consideration should be given to installing a trap or other suitable device in the exhaust line to remove the water, oil or liquid.

Once all the foregoing check points have been attended to, the vacuum system should be operating with satisfactory performance. If performance is still not adequate, the vacuum producer is probably undersized for the job.

Answer to Test Your CEQ

Solution to this problem requires a judicious choice of thermodynamic system. As our system, let us select the tank plus its contents plus the entering air. At the start of the batch process, the entering air is outside the tank and occupies a volume V_b. Then, it is all compressed into the tank by constant barometric pressure P_b. Thus, $W = P_b \Delta V$, where ΔV is the volume change of the entire system. But obviously $\Delta V = -V_b$. Substituting,

$$W = -P_b V_b \quad (1)$$

Now, at the end of the process, the entering air, which has been compressed into the tank, can be pictured as occupying the entire tank capacity of $V_t = 1$ cu. ft. under a partial pressure $P_p = 0.7$ atm. Since there is no net temperature change over the process and air is virtually an ideal gas, we can apply Boyle's Law, as follows:

$$P_b V_b = P_p V_t \quad (2)$$

Considering now the entire process from start to finish, we can write the First Law as shown following:

$$\Delta E = Q - W \quad (3)$$

The material components of our system, however, are inert solid tank walls and a virtually ideal gas. For these substances, $\Delta E = 0$ when there is no net temperature change. Combining this fact with Eq. (1), (2) and (3), yields

$$Q = -P_p V_t \quad (4)$$

or $Q = -0.7 \times 1 = -0.7$ atm. cu. ft. $= -1.91$ Btu.

Thus, 1.91 Btu. leave the system through the tank walls, driven by whatever small transient temperature differences are generated in the process.

As with many thermodynamic problems, alternative systems can be selected, provided care is exercised in correctly identifying the corresponding processes. Occasionally, however, a problem will have alternate, superficially simple, thermodynamically unsound solutions that happen to give the correct answer. The present problem is of this type, so beware.

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CE Cost File

No. 53: Construction Labor Units

R. T. WITHERSPOON, JR.
Estimating Section, The Chemstrand Corp.
Pensacola, Fla.

The tables (*right*) should be helpful when estimating the cost of installing new buildings or additions to existing buildings in chemical process plants.

Man-hours listed are based on several multimillion-dollar industrial and process projects in the southeastern section of the U. S.

Working conditions on these projects were average; and therefore should be increased about 20% if they are used on projects where conditions are poor.

Labor units are the total man-hours of all crafts involved in performing the related unit of work. These units include an allowance for general foreman and unit foreman. They also include an allowance for material handling, layout and cleanup where required.

To convert man-hours into dollars, use the journeyman's rate of the craft listed in the rate column multiplied by the multiplying factor (mult. factor). This converts the journeyman's rate to the average hourly rate for performing this unit of work, and accounts for the difference in wage scales paid foreman, and other crafts associated with this type of work. The craft listed performs the majority of the work.

Example Shows How

To illustrate use of the table, let's work an example: Find the labor cost for forming a concrete wall 4-ft. high by 8-ft. long.

Item	*Unit*	*Man-Hr.*	*Rate*	*Mult. Factor*
Foundation walls				
Forming	sq. ft.	0.18	cpr.	0.90

Assume a carpenter's rate of $3.25/hr. Wall area, one side, is 32 sq. ft. Then: 32 sq. ft. × 0.18 man-hr. × $3.25/hr. × 0.90 = $16.84 labor for forming one side. And $16.84 × 2 = $33.68 for forming both sides.

Man-hours for concrete form work are based on one use of the forms. Where job conditions permit re-use of the forms, these units can be reduced by about 20%. This reduction is based on the following: 20% for fabrication, 60% for handling and erecting and 20% for stripping and cleaning.

Man-hours for pouring concrete are based on chuting concrete into the forms from a ready-mix truck, including hoisting when required.

If it's necessary to use concrete buggies in addition to the above, add 0.5 man-hr. per cu. yd. for all units. These units do not include standby carpenters, ironworkers, fitters or electricians. Their time, where required, must be included in the installation of the item they were originally associated with.

For masonry work, man-hours include working on a scaffold, where required. But man-hours do not include erection or dismantling the scaffold.

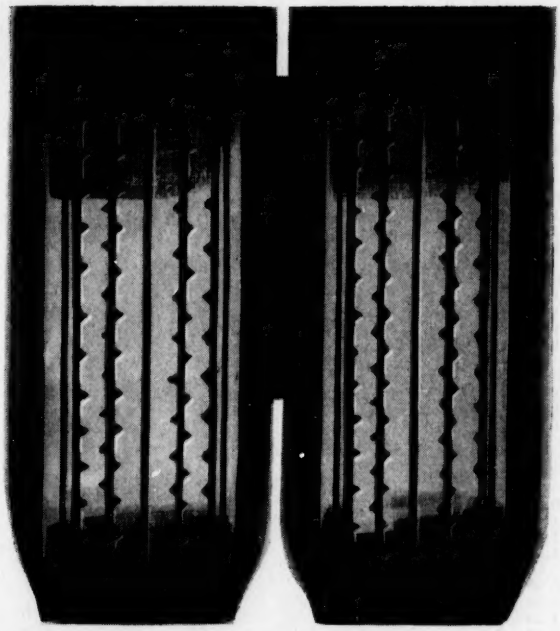
Man-hours for structural steel and miscellaneous iron work include erecting and connecting, plus a nominal amount of unloading, hauling and handling.

Basic Unit Labor in Man-Hours

Excavation; General	Unit	Man-Hr.	Rate	Mult. Factor
Clearing & grubbing	acre	266.0	eo.	0.77
Remove trees, per dia. inch	dia. in.	0.50	lab.	1.13
Grade-out	cu. yd	0.72	eo.	0.95
Grading-fill, compacted	cu. yd.	0.40	eo.	0.95
Grading-borrow	cu. yd.	0.20	eo.	0.95
Rock excavation, mass	cu. yd.	1.14	eo.	0.76
Rock excavation, hand	cu. yd.	11.2	lab.	1.15
Finish Grading & Fencing; General				
Finish grading, hand	sq. yd.	0.20	lab.	1.07
Topsoil & seeding	sq. yd.	0.25	lab.	1.17
Fencing, chain link, 5'	lin. ft.	0.80	lab.	1.08
Roads, & Walks; General				
Gravel fill-delivered	ton	1.28	lab.	1.13
Sand fill-delivered	ton	1.40	lab.	1.13
Pavement, bituminous 2"	sq. yd.	0.80	eo.	0.92
Pavement, conc. mixed on job	cu. yd.	5.2	lab.	1.13
Pavement, conc. ready mix	cu. yd	3.3	lab.	1.13
Curbs, gutter, conc. integral	cu. yd.	7.1	lab.	1.13
Sidewalks, conc. ready mix	cu. yd.	3.12	lab.	1.13
Railroad track 100 lbs	lin. ft.	4.4	lab.	0.68
Railroad ballast-delivered	ton	0.70	lab.	1.18
Railroad-switches-frogs	ea.	400.0	lab.	0.68
Sewers & Drains; Concrete Manholes				
Manhole, standard singular				
Forming	sq. ft.	0.30	cpr.	0.90
Reinforcing rods, place & tie	ton	20.00	iw.	1.06
Concrete pouring	cu. yd	1.50	lab.	1.15
Concrete finishing	sq. ft.	0.04	cf.	1.04
Manhole, irregular singular				
Forming	sq. ft.	0.35	cpr.	0.90
Reinforcing rods, place & tie	ton	20.00	iw.	1.06
Concrete pouring	cu. yd.	1.50	lab.	1.15
Concrete finishing	sq. ft.	0.04	cf.	1.04
Building Piling & Bracing; General				
Piling, raymond, large job	lin. ft.	0.4	pd.	1.0
Piling, monotube, large job	lin. ft.	0.3	pd.	1.0
Piling, wood, large job	lin. ft.	0.2	pd.	1.0
Piling, precast conc.	lin. ft.	1.6	lab.	1.13
Sheet piling, steel, large job	ton	50.0	pd.	1.0
Sheet piling, wood, average depth	sq. ft.	0.24	cpr.	1.0
Shoring, wood 2"	m. b. ft.	38.4	cpr.	0.98
Excavation; General				
Excavation, hand, no hauling	cu. yd.	5.5	lab.	1.07
Excavation, hand and hauling	cu. yd	5.8	lab.	1.15
Excavation, machine, no hauling	cu. yd.	3.6	eo.	0.94
Excavation, machine and hauling	cu. yd.	3.9	eo.	0.94
Excavation, trenching mach. in. bldg	cu. yd.	2.80	eo.	0.88
Backfill, compacted, hand	cu. yd.	2.2	lab.	1.07
Backfill, compacted, pneumatic tamp	cu. yd.	1.8	lab.	1.07
Backfill, compacted, mach. large area	cu. yd.	0.08	eo.	0.95
Backfill, compacted, mach. small area	cu. yd.	0.16	eo.	0.95
Rough grading, mach, large area	sq. ft.	0.023	eo.	0.83
Rough grading, hand, small area	sq. ft.	0.11	lab.	1 07
Finish grading, hand, for slabs	sq. ft.	0.02	lab.	1.07
Gravel fill, average work	cu. yd.	1.6	lab.	1.13
Crushed stone	cu. yd.	1.6	lab.	1.13

(Continued on p. 264)

bl. = block mason; bm. = brick mason; cpr. = carpenter; cf. = concrete finisher; eo. = equipment operator; glaz. = glazier; iw. = iron worker; lab. = laborer; lath. = lather; pd. = pile driver; pf. = pipe fitter; pltr. = plasterer; ptr. = painter; roof. = roofer; sm. = sheet metal; ts. = tile setter.



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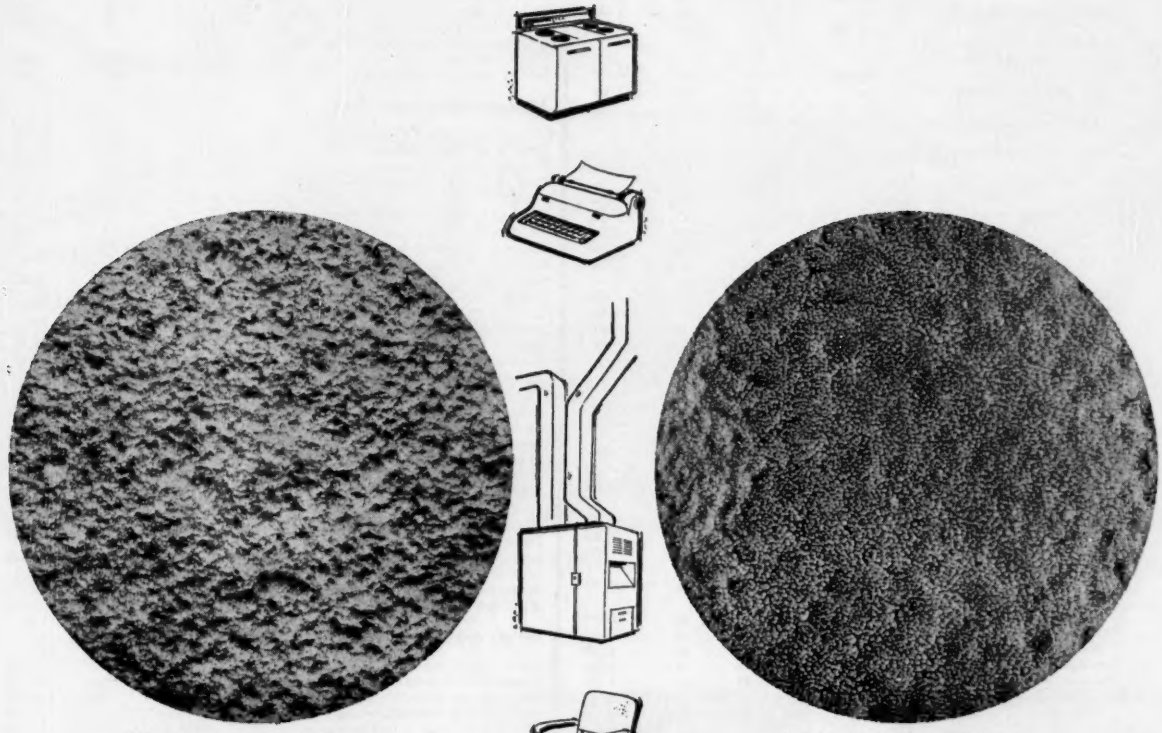
Foundations; Concrete	Unit	Man-Hr.	Rate	Mult. Factor
Footings				
Forming	sq. ft.	0.22	cpr.	0.90
Reinforcing rods, place & tie	ton	20.00	iw.	1 06
Concrete pouring	cu. yd'	1.00	lab.	1.15
Concrete finishing	sq. ft.	0.02	cf.	1.04
Foundation walls				
Forming	sq. ft.	0.18	cpr.	0.90
Reinforcing rods, place & tie	ton	20.00	iw.	1.06
Concrete pouring	cy. yd.	1.20	lab.	1.15
Concrete finishing	sq. ft.	0.05	cf.	1.04
Piers				
Forming	sq. ft.	0.24	cpr.	0.90
Reinforcing rods, place & tie	ton	20.00	iw.	1.06
Anchor bolts	ea.	0.80	cpr.	1.04
Concrete pouring	cu. yd.	1.50	lab.	1.15
Concrete finishing	sq. ft.	0.02	cf.	1.04
Grade beams				
Forming	sq. ft.	0.20	cpr.	0.90
Reinforcing rods, place & tie	ton	20.0	iw.	1.06
Concrete pouring	cu. yd.	1.20	lab.	1.15
Concrete finishing	sq. ft.	0.05	cf.	1.04
Supports; Concrete Construction				
Columns to 10' high				
Forming	sq. ft.	0.24	cpr.	0.90
Reinforcing rods, place & tie	ton	20.00	iw.	1.06
Concrete pouring	cu. yd.	2.50	lab.	1.25
Concrete finishing	sq. ft.	0.04	cf.	1.04
Columns above 10' high				
Forming	sq. ft.	0.30	cpr.	0.90
Reinforcing rods, place & tie	ton	20.50	iw.	1.06
Concrete pou.ing	cu. yd.	2.60	lab.	1.25
Concrete finishing	sq. ft.	0.04	cf.	1.04
Beams & girders to 10' high				
Forming	sq. ft.	0.24	cpr.	0.90
Reinforcing rods, place & tie	ton	20.00	iw.	1.06
Concrete pouring	cu. yd.	2.10	lab.	1.25
Concrete finishing	sq. ft.	0.04	cf.	1.04
Beams & girders above 10' high				
Forming	sq. ft.	0.30	cpr.	0.90
Reinforcing rods, place & tie	ton	20.50	iw.	1.06
Concrete pouring	cu. yd.	2.60	lab.	1.25
Concrete finishing	sq. ft.	0.40	cf.	1.04
Spandrel beams & lintels				
Forming	sq. ft.	0.35	cpr.	0.90
Reinforcing rods, place & tie	ton	20.0	iw.	1.06
Concrete pouring	cu. yd.	2.30	lab.	1.25
Concrete finishing	sq. ft.	0.40	cf.	1.04
Walls; Exterior Masonry				
Wall, rubble stone	cu. yd.	12.0	bl.	0.80
Wall, 12", 8" tile & common brick	sq.	35.0	bl.	0.80
Wall, 12", 8" tile & face brick	sq.	40.0	bl.	0.80
Wall, 12", jumbo brick	sq.	41.0	bl.	0.80
Wall, 12", double size common brick	sq.	84.0	bl.	0.80
Wall, 12", common brick	sq.	50.0	bl.	0.80
Wall, 12", interlocking T tile (6½" x 8" x 12")	sq.	30.0	bl.	0.80
Brick, common, veneer (cy = ½ M)	M	25.0	bl.	0.80
Brick, face, veneer (3¾" x 2¼" x 8")	M	35.0	bl.	0.80
Brick, jumbo, veneer (3½" x 3½" x 7½")	M	30.0	bl.	0 80
Block, concrete, (4" x 8" x 16")	ea.	0.10	bl.	0.80
Block, concrete, (6" x 8" x 16")	ea.	0.125	bl.	0.80
Block, concrete (8" x 8" x 16")	ea.	0.15	bl.	0.80
Block, concrete (12" x 8" x 16")	ea.	0.20	bl.	0.80
Block, cinder (4" x 8" x 16")	ea.	0.09	bl.	0.80
Block, cinder (6" x 8" x 16")	ea.	0.11	bl.	0.80
Block, cinder (8" x 8" x 16")	ea.	0.13	bl.	0.80
Block, cinder (12" x 8" x 16")	ea.	0.18	bl.	0.80
Tile, T.C. load bearing (3¾" x 12" x 12")	ea.	0.10	bl.	0.80
Tile—T.C. load bearing (6" x 12" x 12")	ea.	0.13	bl.	0.80
Tile—T.C. load bearing (8" x 12" x 12")	ea.	0.16	bl.	0.80
Tile—T.C. load bearing (12" x 12" x 12")	ea.	0.20	bl.	0.80
Structural gl. tile 1 side (2" x 5½" x 12")	ea.	0.15	bl.	0.80
Structural gl. tile 1 side (4" x 5½" x 12")	ea.	0.16	bl.	0.80
Structural gl. tile 1 side (6" x 5½" x 12")	ea.	0.17	bl.	0.80
Structural gl. tile 2 side (4" x 5½" x 12")	ea.	0.20	bl.	0.80
Structural gl. tile 2 side (6" x 5½" x 12")	ea.	0.22	bl.	0.80
Glass block, average	sq. ft.	0.35	bl.	0.80
Flat ceramic wall tile (4" x 4")	sq. ft.	0.50	bl.	0.80
Stone veneer, 4" limestone, granite	sq. ft.	0.55	bl.	0.80
Rubble stone walls	cu. yd.	6.0	bl.	0.80
T.C. split furring tile 1½"	sq. ft.	0.07	bl.	0.80
T.C. split furring tile 2"	sq. ft.	0.08	bl.	0.80
Stone work, granite (lintels, coping etc.)	cu. ft.	0.55	bl.	0.80
Precast conc. sills, lintels	lin. ft.	0.30	bl.	0.80
Precast conc. coping, 12" wall	lin. ft.	0.30	bl.	0.80
T.C. coping 8" wall	lin. ft.	0.18	bl.	0.80
T.C. coping 12" wall	lin. ft.	0.22	bl.	0.80
Washing masonry	sq. ft.	0.03	lab.	1.20
Caulking openings	lin. ft.	0.03	bl.	1.03
Scaffolding, tubular, wall face brick	M	2.50	cpr.	0.85
Scaffolding, wall face	sq. ft.	0.035	cpr.	0.85
Walls; Wood Construction, Exterior				
Heavy timber work—columns	m. b. ft.	50.0	cpr.	0.95
Heavy timber work—joist & columns	m. b. ft.	25.0	cpr.	0.95
Framing lumber—average	m. b. ft.	50.0	cpr.	0.95
Rough boarding & sheathing —diagonal	m. b. ft.	27.0	cpr.	0.95
Plywood sheathing	sq. ft.	0.025	cpr.	0.95
Siding 1"x8"	m. b. ft.	30.0	cpr.	0.95
Apply metal lath on wood	sq. yd.	0.10	pltr.	0.85
Stucco—incl. lath	sq. yd.	0.90	pltr.	0.85
Walls; Wood Construction, Interior				
Framing lumber—average	m. b. ft.	50.0	cpr.	0.95
Furring 1x2 or 1x3	m. b. ft.	75.0	cpr.	0.95
Gypsum board, Celotex, etc.	sq. ft.	0.03	cpr.	1.00
Asbestos board, 3/16"	sq. ft.	0.095	cpr.	1.00
Perforated tape joints for wall board	sq. ft.	0.02	cpr.	1.00
Masonite wainscots (4'-5')	sq. ft.	0.15	cpr.	1.00
Caulking (on wood)	lin. ft.	0.05	cpr.	1.00
Apply metal lath on wood	sq. yd.	0.10	pltr.	0.85
Plaster 3 coats on metal lath	sq. yd.	0.44	pltr.	0.85
Plaster 3 coats average, incl. lath	sq. yd.	0.54	pl r.	0.85
Walls; Finishes				
Apply metal lath on wood	sq. yd.	0.10	pltr.	0.85
Plaster, 3 coats on met. lath (no lath)	sq. yd.	0.44	pltr.	0.85
Plaster, 3 coats on masonry (no lath)	sq. yd.	0.44	pltr.	0.85
Plaster, 3 coats average incl. lath	sq. yd.	0.54	pltr.	0.85
Plaster, acoust. 3 coats incl. lath	sq. yd.	0.66	pltr.	0.85
Stucco, incl. lath	sq. yd.	0.90	pltr.	0.85
Steel or aluminum wall panels	sq. ft.	0.16	iw.	1.03
Aluminum insul. wall panels	sq. ft.	0.2	iw.	1.03
Acoustical wall panels	sq. ft.	0.2	iw.	1.03
Gypsum board, Celotex, etc.	sq. ft.	0.03	cpr.	1.00
Masonite wainscots	sq. ft.	0.15	cpr.	1.00
Perforated tape joints for wall board	sq. ft.	0.02	cpr.	1.00
Plywood wainscots	sq. ft.	0.15	cpr.	1.00
Siding—1x8	m. b. ft.	30.00	cpr.	1.00
Paneling, knotty pine, etc	sq. ft.	0.10	cpr.	1 00
Trim, various, average	lin. ft.	1.08	cpr.	1.00
Caulking (on wood)	lin. ft.	0.05	cpr.	1.00
Corrugated asbestos siding on steel	lin. ft.	0.09	cpr.	1.00
Asbestos shingles 8"x16"	lir . ft.	0.09	cpr.	0.90
Asphalt strip shi gles	lin. ft.	0.02	cpr.	0.90
Transite siding	lin. ft.	0.09	cpr.	1 00
Corr. galbestos	lin. ft.	0.07	iw.	1.03
Floors; Concrete				
Concrete slab on ground				
Forming (if necessary)	sq. ft.	0.18	cpr.	0.90
Screeds	sq. ft.	0.005	cpr.	0.90
Reinforcing rods, place & tie	ton	20.00	iw.	1.06
Reinforcing mesh, place & tie	sq. ft.	0.01	iw.	1.06
Concrete pouring (small slab)	cu. yd.	1.30	lab.	1.15
Concrete pouring (large slab)	cu. yd.	1.10	lab.	1 15
Concrete finishing (wood float)	sq. ft.	0.02	cf.	1 04
Concrete finishing (steel trowel)	sq. ft.	0.04	cf.	1.04
Concrete finishing (special fin.)	sq. ft.	0.01	cf.	1.04

(*Continued on p. 266*)

bl. = block mason; bm. = brick mason; cpr. = carpenter; cf. = concrete finisher; eo. = equipment operator; glaz. = glazier; iw. = iron worker; lab. = laborer; lath. = lather; pd. = pile driver; pf. = pipe fitter; pltr. = plasterer; ptr. = painter; roof. = roofer; sm. = sheet metal; ts. = tile setter.



This finish contains
quality controlled
Plaskon Coating Resin

This finish contains
ordinary coating resin

Compare these two unretouched photographs of hammertone finishes on "24 gauge" steel panels. Notice the more uniform pattern and freedom from mottling in the finish on the left. It is made with quality controlled Plaskon Coating Resin. Poor quality raw materials can cause the blotchy, irregular appearance so obvious in the right hand panel.

Quality control checks are run on Plaskon Coating Resins throughout their manufacture . . . from selection of raw materials to finished resins. True . . . this extra care and attention costs a little more . . . but measured in terms of customers' satisfaction it is a shrewd investment. More details? Drop us a line.

PLASTICS DIVISION
40 RECTOR STREET, NEW YORK 6, N. Y.

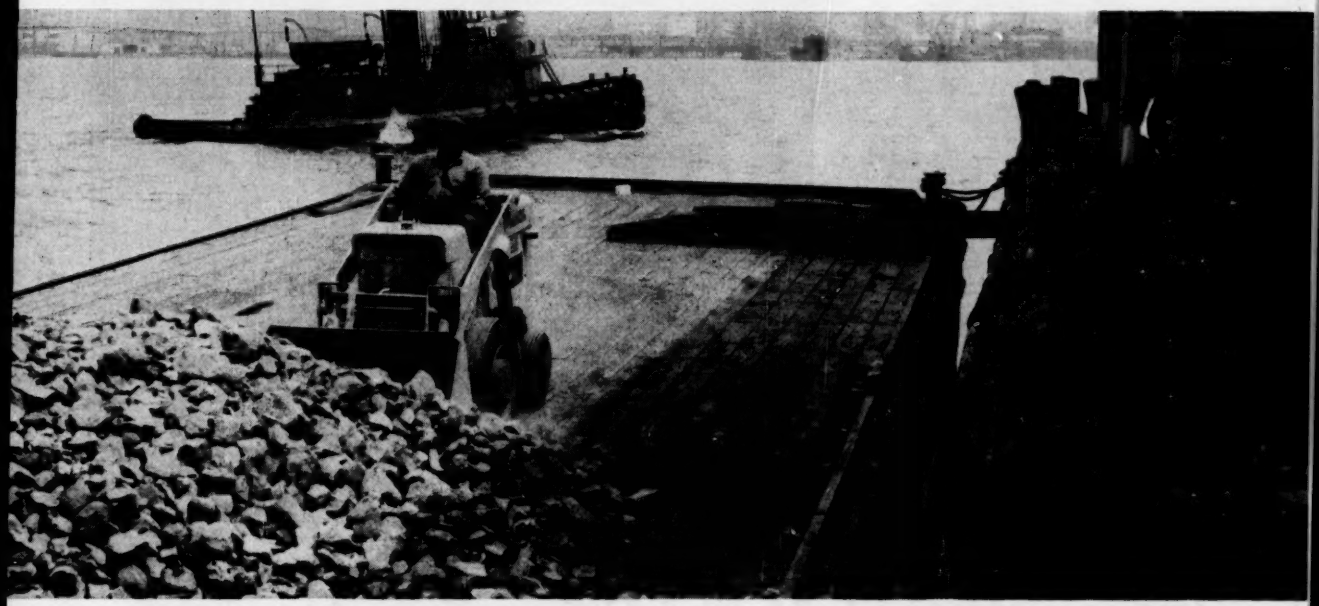
Allied Chemical
BASIC TO AMERICA'S PROGRESS

Floors; Concrete (Cont.)	Unit	Man-Hr.	Rate	Mult. Factor
Concrete curing	sq. ft.	0.01	cf.	1.04
Concrete slab, 2nd floor				
Forming	sq. ft.	0.20	cpr.	0.90
Reinforcing rods, place & tie	ton	20.00	iw.	1.06
Concrete pouring	cu. yd.	2.10	lab.	1.25
For finish see slab on ground				
Concrete slabs, 3rd floor				
Forming	sq. ft.	0.22	cpr.	0.90
Reinforcing rods, place & tie	ton	20.50	iw.	1.06
Concrete pouring	cu. yd.	2.2	lab.	1.25
For finish see slab on ground				
Concrete slabs, 4th floor				
Forming	sq. ft.	0.24	cpr.	0.90
Reinforcing rods, place & tie	ton	20.50	iw.	1.06
Concrete pouring	cu. yd.	2.30	lab.	1.25
For finish see slab on g ound				
Floors; Wood Frame & Finishes				
Framing lumber	m. b.f t.	50.0	cpr.	0.95
Subflooring—diagonal	m. b. ft.	22.0	cpr.	0.95
Subflooring—plywood	sq. ft.	0.025	cpr.	0.95
Finish flooring, softwood	m. b. ft.	23.0	cpr.	0.95
Finish flooring, hardwood	m. b. ft.	34.0	cpr.	0.95
Asphalt or rubber tile, 9"x9"	sq. ft.	0.04	cpr.	1.00
Asphalt or rubber tile, 12"x12"	sq. ft.	0.03	cpr.	1.00
Linoleum ⅛" on wood	sq. ft.	0.04	cpr.	1.00
Cork floor tile 6"x6"x¼"	sq. ft.	0.10	cpr.	1.00
Lining felt	sq. ft.	0.01	cpr.	1.00
Sanding floor—machine	sq. ft.	0.013	cpr.	1.00
Floor Covering or Finishing				
Asphalt or rubber tile 9"x9" on concrete	sq. ft.	0.04	cpr.	1.00
Asphalt or rubber tile 12"x12" on concrete	sq. ft.	0.03	cpr.	1.00
Linoleum ⅛" on concrete	sq. ft.	0.04	cpr.	1 00
Linoleum ⅛" on wood	sq. ft.	0.05	cpr.	1.00
Sanding floor	sq. ft.	0.013	cpr.	1.00
Finish flooring (soft wood)	m. b. ft.	23.00	cpr.	0.95
Finish flooring (hardwood)	m. b. ft.	34.00	cpr.	0.95
Cork floor tile 6"x5"x¼"	sq. ft.	0.10	cpr.	1.00
Quarry tile—6x6—incl. 3" cement fill	sq. ft.	0.25	ta.	0.80
Terrazo—2'-0" squares incl. 1¼" underbed	sq. ft.	0.25	ta.	0.80
Acid brick floor	sq. ft.	0.60	bl.	0 80
Carborundum rubbing	sq. ft.	0.01	cf.	1.00
Granolithic finish	sq. ft.	0. 4	cf.	1.00
Hardner, surface—liquid	sq. ft.	0.01	cf.	1.00
Marble tile—incl. cement bed	sq. ft.	0.50	ta.	0.80
Lining felt	sq. ft.	0.01	cpr.	1.00
Roof Decks; Concrete				
Concrete roof slabs				
Forming	sq. ft.	0.24	cpr.	0.90
Reinforcing rods, place & tie	ton	20.50	iw.	1.06
Concrete pouring	cu. yd.	2.30	lab.	1.25
Concrete finishing	sq. ft.	0.02	cf.	1.04
Roof Decks; Metal				
Steel roof deck				
Steel roof deck 18 or 20 gage	sq. ft.	0.04	iw.	1.03
Roof Decks; Wood				
Roof deck, wood				
Roof decking, diagonal board	m. b. ft.	27.0	cpr.	0.95
Roof decking, plywood	sq. ft.	0.025	cpr.	0.95
Roofing; General				
Roll roofing, nailed	sq. ft.	0.016	cpr.	1.00
Build up, 4 ply, t & g	sq. ft.	0.025	roof.	1.05
Slate or tile	sq. ft.	0.08	roof.	1.00
Corr. metal, soga on steel frame	sq. ft.	0.05	iw.	1.03
Corr. asbestos, on steel frame	sq. ft.	0.065	cpr.	1.00
Ridge rools	lin. ft.	0.10	cpr.	1.00
Gutters & down spouts, metal	lin. ft.	0.13	sm.	1.00
Gravel stops, metal	lin. ft.	0.07	sm.	1.00
Flashing, metal	lin. ft.	0.07	sm.	1.00
Structural Steel; General				
Unloading, hauling & handling	ton	4.0	iw.	1.03
Unloading & handling	ton	3.0	iw.	1.03
Setting base plates	ton	50.0	iw.	1.03
Heavy skeleton frame, new	ton	15.0	iw.	1.03
Heavy skeleton frame, alterations	ton	20.0	iw.	1.03
Light mill or whse. type, new	ton	20.0	iw.	1.03
Light mill or whse, type, alterations	ton	25.0	iw.	1.03
Bar joists (large size or quantity)	ton	12.0	iw.	1.03
Bar joists, (small size or quantity)	ea.	1.2	iw.	1.03
Field riveting only, per hundred	C	16.5	iw.	1.03
Field riveting only	ton	4.0	iw.	1.03
Field bolting only, per hundred	C	5.5	iw.	1.03
Field bolting only	ton	3.0	iw.	1.03
Field welding only, average job	ton	3.0	iw.	1.03
Field fabrication only, average job	ton	15.0	iw.	1.03
Setting up 40' hand operated derrick	ea.	45.0	iw.	1.03
Setting up light steel derrick	ea.	9.0	iw.	1.03
Miscellaneous Iron Work				
Unloading, hauling & handling	ton	6.0	iw.	1.03
Stair & platform framing	ton	40.0	iw.	1.03
Toe plates for platforms, etc	lin. ft.	0.20	iw.	1.03
Grating ¾"x1¼" shop fab. erect only	sq. ft.	0.20	iw.	1.03
Grating ¾"x1¼" field fab. erect	sq. ft.	0.25	iw.	1.03
Checker plate shop fab. erect only	sq. ft.	0.20	iw.	1.03
Checker plate field fat. erect only	sq. ft.	0.25	iw.	1.03
Checker plate erect only	ton	40.00	iw.	1.03
Ladders, steel, only	lin. ft.	1.00	iw.	1.03
Ladders, steel with cage	lin. ft.	1.40	iw.	1.03
Window guards, bartype	ea.	1.00	iw.	1.03
Window guards, mesh type	ea.	1.00	iw.	1.03
Anchor bolts	lb.	0.20	iw.	1.03
Curb angles, straps, unistruts	lb.	0.10	iw.	1.03
Lintels, door bucks	lb.	0.05	iw.	1.03
Pipe, columns, posts, misc. angles.	lb.	0.05	iw.	1.03
Sleeves, dowels	lb.	0.10	iw.	1.03
Ductwork & breeching	ton	50.0	bm.	1.03
Steel stacks 30"x30'-0"	ea.	80.0	bm.	1.03
Steel stacks 30"x60'-0"	ea.	120.0	bm.	1.03
Steel stacks, 30"x80'-0"	ea.	140.0	bm.	1.03
Steel stacks, 30"x100'-0"	ea.	160.0	bm.	1.03
Steel stacks, general	ton	55.0	bm.	1.03
Field fabrication only, average job	ton	25.0	bm.	1.03
Field fabrication only, average job	ton	15.0	iw.	1.03
Lath for slab on bar joist	sq. ft.	0.011	lath.	1.03
Lath for ceiling under joist	sq. ft.	0.017	lath.	1.03
Steel bins, hoppers, plate work	ton	40.0	iw.	1.03
Field welding, average job	ton	2.0	iw.	1.03
Doors & Frames; Windows & Frames; Louvres				
Door frames, metal	lb.	0.05	iw.	1.03
Doors, hollow metal, complete	sq. ft.	0 40	cpr.	1 00
Doors, wood, complete swing	sq. ft.	0 30	cpr.	1 00
Doors, wood, complete overhead	sq. ft.	0.25	cpr.	1.00
Doors, met. clad, complete, swing.	sq. ft.	0.65	cpr.	1.00
Doors, rolling steel	sq. ft.	0.30	iw.	1.03
Windows, steel, complete	sq. ft.	0.08	iw.	1.03
Windows, wood, complete	sq. ft.	0.25	cpr.	1.00
Louvres, metal, complete	sq. ft.	0.15	iw.	1.03
Louvres, wood, complete	sq. ft.	0.15	cpr.	1.00
Screen doors, complete	sq. ft.	0.10	cpr.	1.00
Glazing, wood sash	sq. ft.	0.07	glaz.	1.05
Glazing, steel sash	sq. ft.	0.12	glaz.	1.05
Weatherstripping-windows	ea.	1.70	cpr.	1.00
Insulation; General				
Cork on masonry, 2"—2 layers	sq. ft.	0.20	cpr.	0.90
Gypsum plank, 2"—metal edge	sq. ft.	0.019	cpr.	1.00
Rock wool 4"—loose or bulk	sq. ft.	0.025	cpr.	1.00
Rock wool 4"—batts	sq. ft.	0.015	cpr.	1.00
Painting; General				
Structural steel, 1 coat	ton	3.00	ptr.	1.00
Grating, 1 coat	sq. ft.	0.02	ptr.	1.00
Floor plate, 1 coat	sq. ft.	0.01	ptr.	1.00
Hand rails, 1 coat	lin. ft.	0.02	ptr.	1.00
Sash & doors, 1 coat	sq. ft.	0.015	ptr.	1.00
Walls & flat surfaces, 1 coat	sq. ft.	0.01	ptr.	1.00
Piping, conducts, 1 coat	ton	10.00	ptr.	1.00
Equipment, 1 coat	ton	2.00	ptr.	1.00
Signs, plain	sq. ft.	0.25	ptr.	1.00
Hardwood floors	sq. ft.	0.15	ptr.	1.00
Miscellaneous				
Hose racks (no piping)	ea.	2.0	pf.	1.00
Fire extinguisher—portable	ea.	0.20	pf.	1.00
Scaffolding, tublar, wall face area	sq. ft.	3.50	iw.	1.03
Cleanliness control, floors (per day)	sq. ft.	0.015	lab.	1.05
Sandblasting—flat areas	sq. ft.	0.02	lab.	1.40
Toilet stalls, wood	ea.	8.00	cpr.	0.95

bl. = block mason; bm. = brick mason; cpr. = carpenter; cf. = concrete finisher; eo. = equipment operator; glaz. = glazier; iw. = iron worker; lab. = laborer; lath. = lather; pd. = pile driver; pf. = pipe fitter; pltr. = plasterer; ptr. = painter; roof. = roofer; sm. = sheet metal; ts. = tile setter.

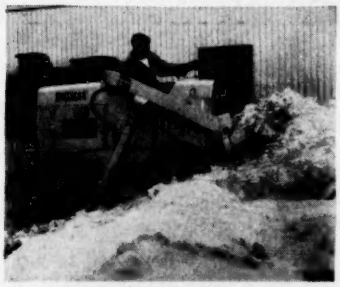
TOUGH MATERIAL SPECIALIST—

The Model 12B Michigan

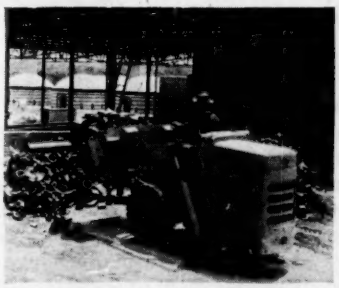


CHROME and CARBORUNDUM ORE are unloaded fast by this 16 cu ft Model 12B. Owner: New York Central RR. Location: Jersey City.

Like all Michigans, the 12B has efficient all-Clark power train, including power-shift transmission, torque converter, planetary-wheel drive axle.



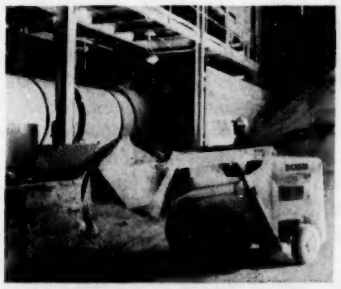
BROKEN GLASS reclaiming is the prime use of this Michigan Model 12B owned by Fairmount Glass Works, Indianapolis, Indiana.



BROKEN TILE, 400 tons per 8 hour day—that's the output of the two 12B's owned by Oconee Clay Products Co., Milledgeville, Georgia.

DOLOMITE, charged directly into red-hot open hearths, is this Michigan's tough, but successful assignment in this Illinois steel plant.

COKE, used by American Brake Shoe Co, Buffalo, is dumped into hopper. Note cramped quarters easily negotiated by the Model 12B.



FERTILIZER, tight-packed and hard to dig, yields to powerful Virginia-owned Model 12B. Note the heaped bucket, a "trademark" of all Michigans.

Your "tough jobs," too, are made to order for Michigan Tractor Shovels. Model 12B capacity is 3,000 lbs, buckets are available to carry from 6 to 27 cubic feet. Write for details.

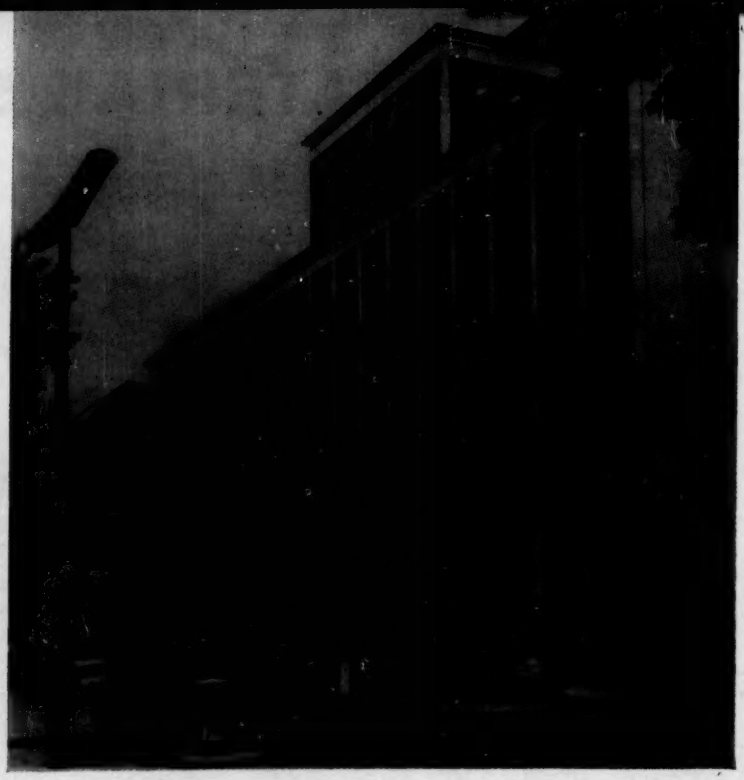
Michigan is a registered trademark of

CLARK EQUIPMENT COMPANY
Construction Machinery Division

CLARK EQUIPMENT

2477 Pipestone Road
Benton Harbor 34, Michigan
In Canada:
Canadian Clark, Ltd.
St. Thomas, Ontario

Corrosion Forum



International Metal-Corrosion Congress

Imperial College, London, was the meeting place for corrosion researchers from all over the world. Here are highlights from a few of the papers presented.

London was the place, and April 10-15 the time of the 1st International Congress on Metallic Corrosion. Of interest to all those working in the corrosion field, the meeting was truly international in attendance. Papers were given by scientists from the U. S. and U.S.S.R., Finland and India, Holland and Australia, Poland and Burma, and many more.

Papers covered the gamut from fundamental studies to "practical experience" and covered such diverse fields as inhibitors, metallic coatings, corrosion fatigue, experimental methods, and intergranular and stress corrosion.

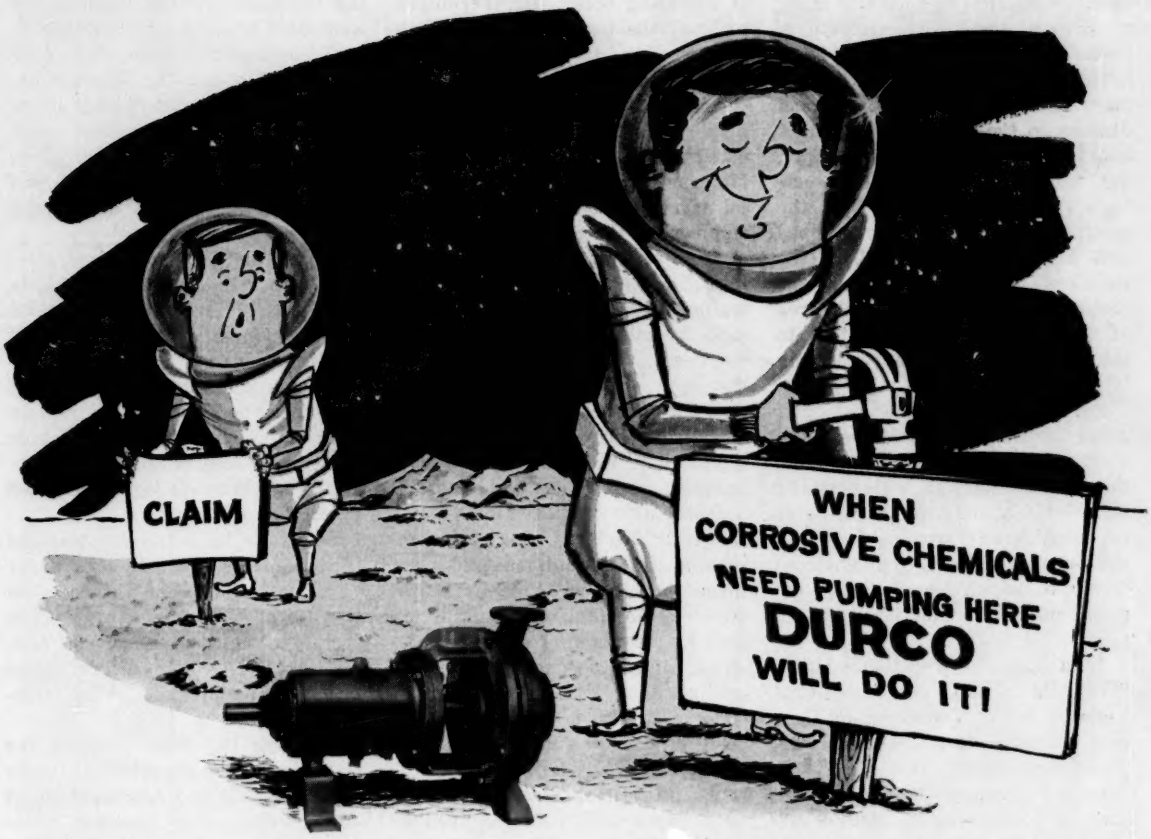
As the original papers fill 531 pages of a quarto volume, we can only summarize some of the high points of a few papers of especial interest to chemical engineers.

Mars G. Fontana of Ohio State University presented a paper on unusual corrosion problems in the chemical process industries. One failure he described was that of a $20,000 high-pressure autoclave made from Type 304 stainless. Although a noncorrosive material was being processed, alternate wetting and drying, which permitted concentration of chloride, leached from the insulation, caused stress-corrosion cracking from the outside inward. This 2-in.-thick vessel handled only a few batches—a matter of hours of operation—before it failed. Several other similar failures are described, which involved wetting of the stainless from vapor-phase condensation.

Temperature effects are too often ignored. If a material gives good service at one temperature, it may be specified for use at a "slightly" higher temperature—sometimes with disastrous results. Dr. Fontana described a plant purifying aluminum oxide from bauxite, operating at 325 F. To get better thermal efficiencies, a new plant was built to operate at 400 F. Both units were constructed of carbon steel. After a short time, pumps and valves began to fail in the high-temperature plant. Then the heat exchanger tubes started to go. Use of more corrosion-resistant parts for critical pump and valve parts, and decreasing velocities through heat exchangers, solved these two problems. But when the 16-in. heavy-wall steel lines started to leak, the plant was in real trouble. The pipes had to be lined with nickel, resulting in much downtime and more expense.

Although most engineers are aware of galvanic corrosion—the increased corrosion of one metal in contact with a more-resistant metal—few are familiar with the "area effect." A small anodic area, in contact with a large cathodic area can be especially troublesome.

One unusual problem of this sort



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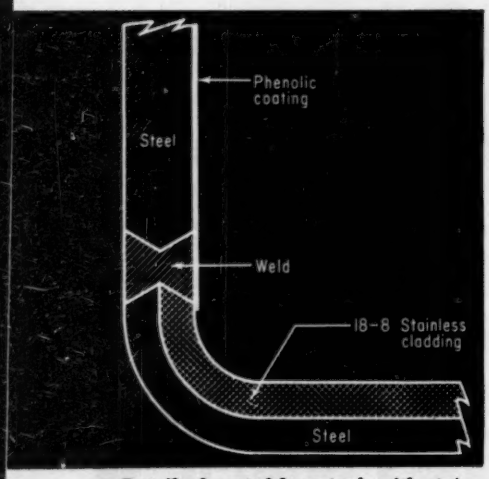
occurred in a large plant making beer. Beer tanks are usually made of carbon steel covered with a phenolic coating. Although long-lasting, the bottoms of these tanks may fail because of mechanical damage to the coating. This plant had tanks made in the usual way, but with 18-8 stainless clad bottoms. The figure shows how the coating on the carbon steel stopped just beyond the point where the stainless began. Defects in the coating exposed a very small area of the carbon steel in relation to the large stainless area, resulting in failures.

Dr. Fontana pointed out that many failures of stainless and aluminum result from pitting from the outside, or the water-cooling side. Usually, only the process side is considered when designing equipment. All of the environments to which the metal is exposed must be considered in the design.

In a paper provocatively titled, "What I'd Like to Know About Corrosion," D. A. Vermilyea of General Electric, discussed the atomic processes involved. One of the reasons corrosion prevention is still more art than science is our lack of knowledge of details at the atomic level. We normally think of metals as being homogeneous continua. On an atomic scale, a metal is certainly not continuous, but it is on this scale that individual acts of corrosion occur. Dr. Vermilyea outlined the present knowledge in this area, and offered a number of suggestions for needed work.



Detail of coated beer tank with stainless-clad bottom.

Accelerated corrosion testing of metals was the subject of several papers. W. D. McMaster of General Motors Corp. described the historical development of these tests. He emphasized the problem of control of tests so that they remain meaningful. Too often, inadequately trained personnel perform tests in such a manner as to make them worthless. McMaster stated, "In the light of the talent available, it seems almost incredible that a simple test procedure should take 40 years to reach a degree of refinement that makes it generally acceptable."

Merely buying a piece of commercial testing equipment does not mean that one will thereby be assured of acceptable results. Short cuts are the bane of a testing program, unless they are thoroughly evaluated.

As a result of the confusion in testing, many engineers are unwilling to accept any test results.

An interesting case of corrosion in a paper mill was described by M. H. Tikkamen of the Institute of Technology, Helsinki, Finland. A welded 18-8 (unstabilized) stainless steel flange failed after use in a sulfite pulp mill. The flange had a thickness of 25 mm. and the pipe, made of exactly the same material had a 3-mm. thickness. The steel analyzed as 18.6% Cr, 8.6% Ni and 0.1% C.

Typical weld decay occurred on the flange side only; the other side of the weld was corrosion-free. A microscopic examination showed that damage was due to heating during the welding operation. The carbide network along the grain boundaries was clearly visible. But, since the pipe was made of exactly the same material as the flange, why didn't the same thing occur on the other side of the weld?

The conventional answer was that this was a case of crevice corrosion caused by stagnant liquid in the flange joint. Still, this didn't occur at other similar joints investigated in the same process.

Prof. Tikkanen found that, during the welding, both sides of the weld were brought into the dangerous temperature zone—the zone conducive to carbide segregation. The thin pipe-wall cooled very rapidly, and the time was so short that no damage was caused. But, the thick flange stored enough heat so that cooling was slow enough for segregation to occur.

Of course, an unstabilized steel with a carbon content as high as 0.1% should never have been used in equipment that had to be welded and then exposed to a very corrosive environment. The dimensions of the flange caused it to remain too hot too long, leading to carbide segregation that in turn led to damage by a corrosive liquid, assisted by crevice action.

Corrosion by sea water was the theme of T. Howard Rogers' paper "Practical Corrosion Problems in the Royal Canadian Navy." The Canadian navy is relatively new, and corrosion engineers have played an important part in its development.

Not bound by long tradition, the Canadians have experimented with new materials and new methods of construction. For example, there is widespread use of plastics. The navy is already using plastic-covered steel boats, and plastic-covered steel minesweeping equipment, as well as plastic gun covers and gun shields. Generally a glass-fiber-reinforced polyester has been used, and results have been very encouraging.

There is also considerable experimentation on the use of plastic piping on seagoing craft. Standard PVC plastic pipe has been found satisfactory for cold water—both fresh and salt. No economic plastic has yet been found for hot water. Neither has a satisfactory joining method been found. The only successful type of joint is a welded one, which is too expensive.

Plastic pipe has one major advantage over metal. This is its excellent shock resistance. During the winter naval exercise of 1960, bad storms caused cracking of a number of metal pipes and fittings, but no cracking was reported in the plastic piping systems.

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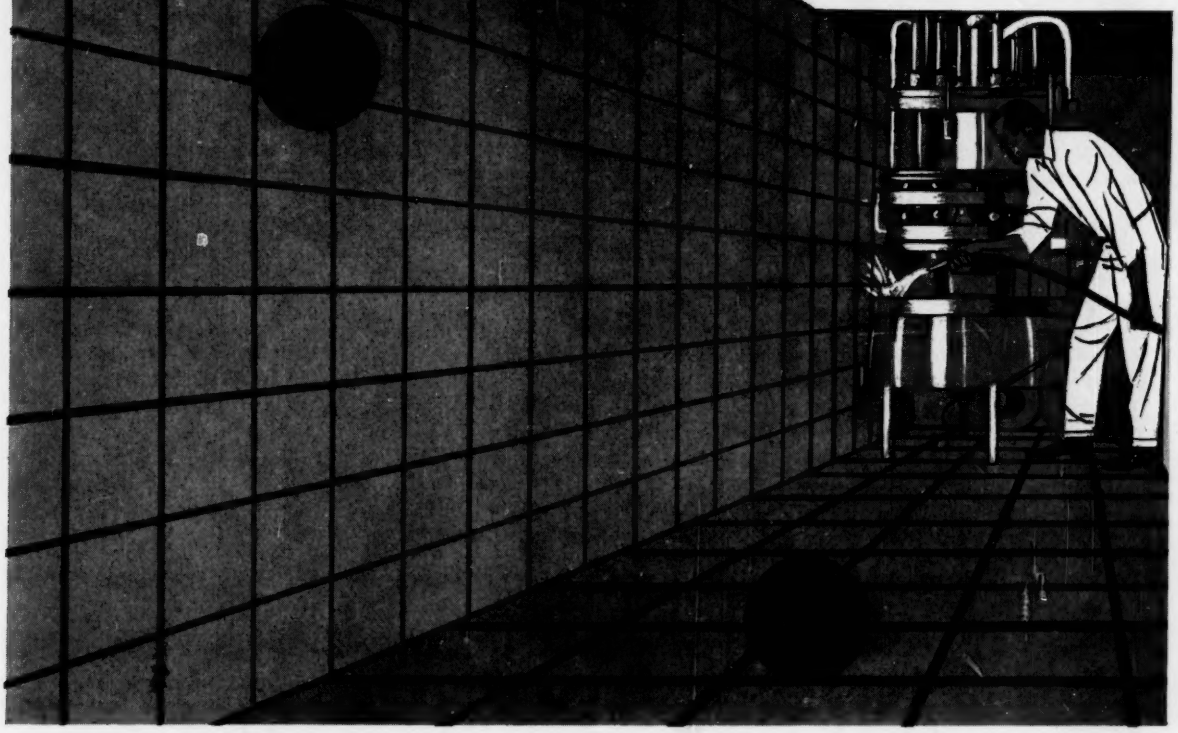

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FURTHER TEST RESULTS ON CORROSION OF PLASTICS

The increased amount of corrosion data now available has made it possible for users, designers and fabricators of corrosion-resistant equipment, such as tanks, hoods and ducts, to specify with confidence the plastic most suitable for a required end-use.

So stated S. S. Feuer of Atlas Powder Co., who has been running a series of corrosion-resistance tests on several different plastics.

Results of tests on three different polyesters were recently reported in Corrosion Forum (*Chem. Eng.*, Apr. 3, p. 182). Of the three polyesters—general purpose, isophthalic and Bisphenol A—only the Bisphenol A showed outstanding resistance to the eight test solutions employed.

The tests graphed below are an extension of the three previously reported. These include a room-temperature-cured Bisphenol A polyester and a triethylenetetramine-cured epoxy. The two heat-cured resins are a Bisphenol A (similar to the one reported in the previous article) and a metaphenylene diamine-cured epoxy.

In this experiment, the same eight corrosive solutions were used: distilled water, 25% sulfuric acid, 5% sodium hydroxide, 5% nitric acid, 15% hydrochloric acid, 25% acetic acid, Clorox (5.25% sodium hypochlorite) and 5% Electrosol (an alkaline, commercial dishwashing detergent). All solutions were held at 210 F. Duration of the tests was six months.

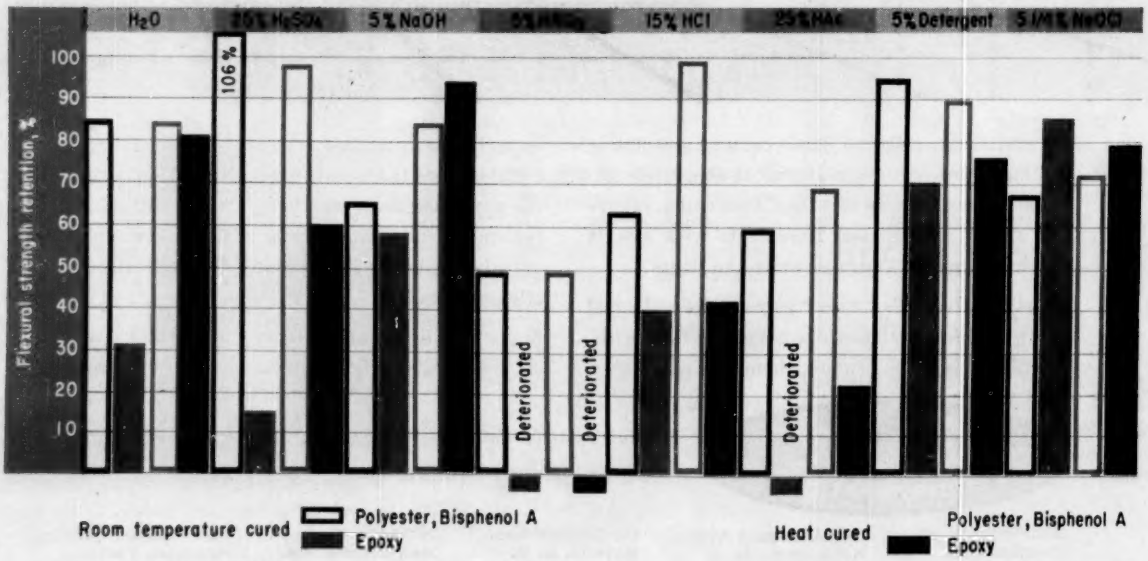
Of the heat-cured castings, the Bisphenol A polyester and the MPD-cured epoxy both showed fairly good resistance but the polyester was better. Under acid conditions, the epoxy tended to break down. Surface attack was noted after one month in 5% nitric acid and the sample suffered complete deterioration at six months. In acetic acid, flex strength retention of the epoxy was only 22% at six months and the castings became opaque in sulfuric, hydrochloric and acetic acids, and distilled water. The epoxy surpassed the Bisphenol A polyester in sodium hydroxide and Clorox.

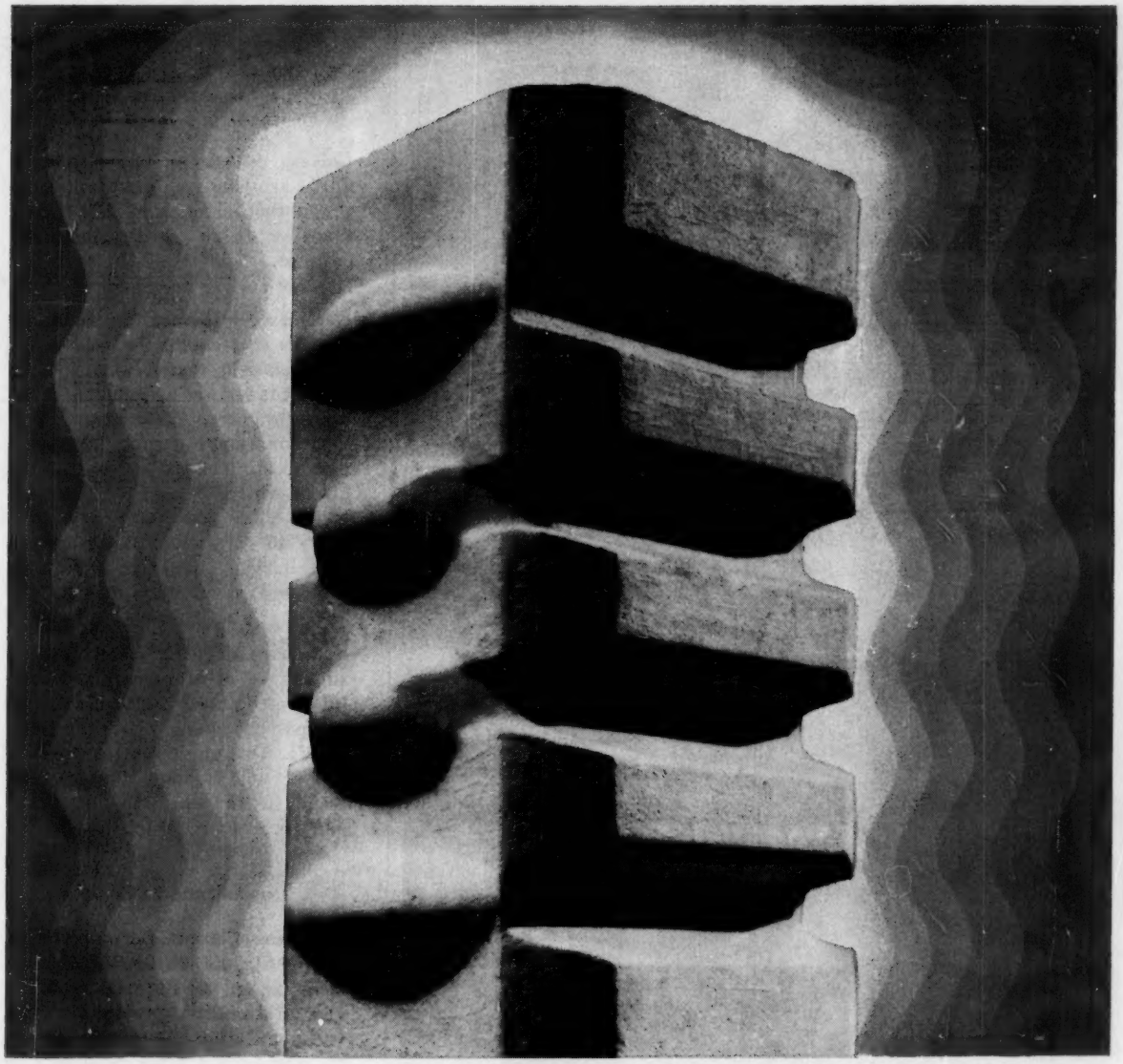
The room-temperature-cured Bisphenol A polyester and the triethylenetetramine-cured epoxy were markedly different; the epoxy was far inferior. The epoxy broke down completely in nitric and acetic acids and lost most of its strength in sulfuric. The epoxy samples turned opaque and black in sulfuric, hydrochloric and acetic acids. Only in Clorox did the epoxy outperform Bisphenol A.

According to Mr. Feuer, these results cannot be used to predict the behavior of epoxies in general. A specific type of cure for an epoxy may provide satisfactory resistance over a narrow range of corrosive media.

The broad range of resistance of Bisphenol-A polyester makes it particularly desirable where corrosive materials other than those originally considered may be used.

These tests were carried out on the resins themselves, not laminates such as are usually used in equipment fabrication. However, tests made on laminates of the three polyesters previously reported showed little difference in results. Two reversals in resistance were noted—both for the isophthalic polyester. Sulfuric acid, which had little effect on the casting, had a serious effect on the laminate. On the other hand, distilled water affected the casting, but had almost no effect on the laminate.





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By using the full potential of ALCOA® Aluminas, Harbison-Walker Refractories Company has developed a remarkable mullite-bonded corundum refractory that is free of the common shortcomings of other super refractories.

Called Korundal XD, it combines extraordinary strength, high density and low porosity. It may be formed into intricate shapes. It is singularly resistant to destructive furnace atmospheres, abrasion and slag attack. And, significantly, it is reasonably priced.

Proof of performance? Korundal XD shows no subsidence in the 25 psi, 3,000°F hot load test after 100 hours. Additional tests showed subsidence of 0.2 per cent after 24 hours at 3,100°F, only 2.0 per cent after 24 hours at 3,200°F, and no spalling loss in the ASTM panel spalling test after 3,000°F preheat.

Korundal XD has been used successfully as skid rails in slab heating furnaces and enamel melting furnaces, as kiln furniture in operations too hot for cordierite and silicon carbide, and in checker chambers where very high temperatures are encountered. Promising new applications include vertical lime kilns, vanadium pentoxide fusion furnaces, combustion areas of carbon black furnaces, electric furnace roofs and tapping holes of iron blast furnaces. Clearly, Korundal XD is destined for the super blast furnaces of the future.

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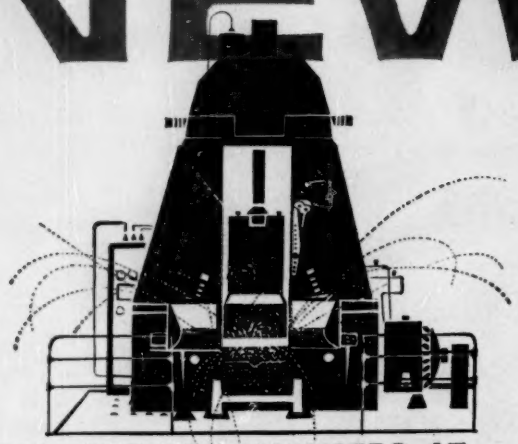

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CPI NEWS BRIEFS . . .

(Continued from page 106)

Kaiser Aluminum & Chemical Corp., showing similar optimism in the market, announced that it had reopened three of its aluminum potlines.

Bureau of Mines of the Dept. of Interior has established a helium research center at Amarillo, Tex., under the federal helium-conservation program. Laboratory will study characteristics and possible new uses of the gas—a year's supply of which, Secretary of the Interior Udall has said, is wasted every 45 days when natural gases are burned without extracting their helium values.

Novamont Corp., a wholly owned subsidiary of Montecatini, Milan, Italy, is building a 25-million-lb./yr. polypropylene plant at Neal, W. Va. Due on stream in the fall, facility will turn out Montecatini's trademarked resin, Moplen. Product will be marketed by W. R. Grace & Co.'s Polymer Chemicals Div.

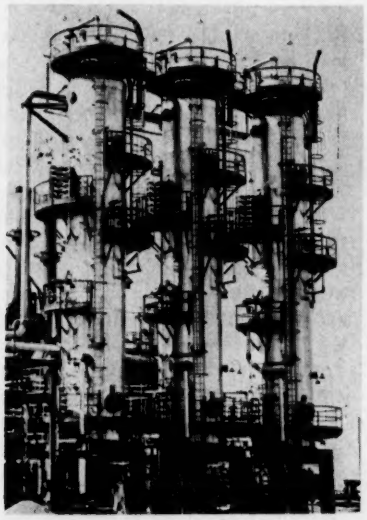
Arkansas Cement Corp. plans to double its 1.4-million-bbl./yr. cement capacity at Foreman, Ark. To cost $7.5 million, project includes the installation of a mammoth (450 ft. long, 12 ft. round) gas-fired kiln alongside the existing oven.

Iowa State University, Ames, Iowa, has awarded a $3.3-million contract to Maxon Construction Co., Dayton, Ohio, to build a 5,000-kw. nuclear research reactor on the campus by early 1963. Unit will be the second at Iowa State's budding Ames Laboratory.

Reichhold Chemicals, Inc., has placed its $4-million, 20-million-lb./yr. maleic anhydride plant on stream at Elizabeth, N. J. Process is company's own, based on air oxidation of benzene over a fixed-bed catalyst—the same route Reichhold licensed to California Chemical Co. for the latter's maleic anhydride plant just on stream in

Richmond, Calif. Constructed by Badger Mfg. Co., Reichhold's unit is adjacent to the firm's $5-million, fluid-bed phthalic anhydride facility, on stream since last year.

Pure Oil Co. plans a 26-million-gal./yr. aromatics unit for its Lemont, Ill., refinery. Due on stream in November, facility will turn out benzene, toluene, and xylene.



Sun Oil Co. has placed its 10,500-bbl./day, $3.6-million propane deasphalter on stream at Toledo, Ohio. Unit boosts firm's catalytic-cracking stock for gasoline, but reduces its capacity for heavy fuel oil. Heart of the installation (shown above) : three 70-ft.-high, 9-ft.-wide disk-contacting towers.

Douglas Oil Co., Paramount, Calif. (currently being acquired by Continental Oil Co.), has bought 400 acres of deepwater frontage on Suisson Bay near Pittsburg, Calif., for close to $1 million. Company refuses either to confirm or deny trade rumors that a refinery is planned for the strip. Four other refineries are already located on the heavily industrialized bay.

Westinghouse Electric Corp. has been awarded a $786,000 contract to fabricate 1,739 fuel assemblies (containing 20,000 tons of "slightly" enriched uranium oxide) for its Experimental Gas-

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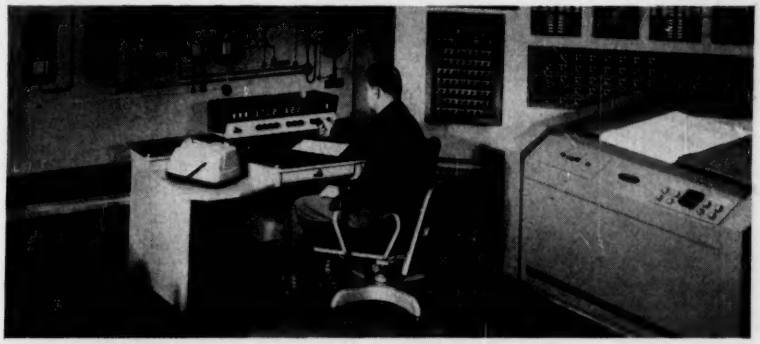

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CPI NEWS BRIEFS . . .

Cooled Reactor under construction at Oak Ridge. Scheduled for operation late in 1962, reactor will turn out 24 mw.

Bunker Hill Co. has begun assaying mine concentrates in a new $100,000 laboratory at its wet-process phosphoric-acid plantsite in Kellogg, Ida. A little over a third of the laboratory's 6,700 sq. ft. of floorspace is underground.

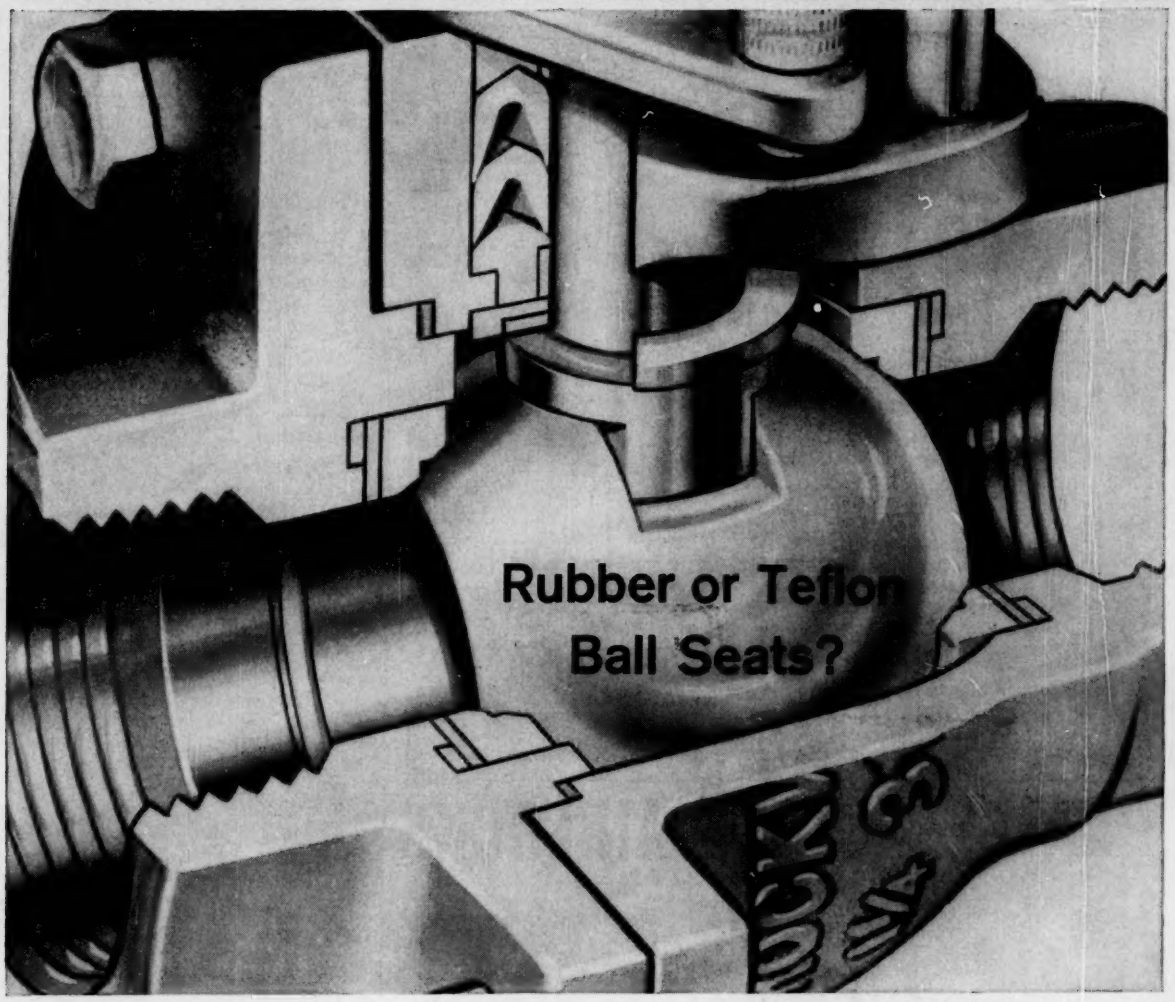
Rocketdyne Div. of North American Aviation, Inc., will build and operate a 15-20,000-gal./day water desalination plant at Oxnard, Calif., under patent license from L. Rosenstein and M. Goren, San Francisco inventors. Designed without heat exchangers, installation will cost $250,000 to build; total research expense is pegged at $1 million. Process is four-step: (1) precooling by mixture with a hydrocarbon such as octane, (2) freezing by butane injection, (3) continuous washing of brine-caked ice crystals with fresh water, (4) melting the crystals with compressed butane.

American-Marietta Co.'s Adhesive, Resin & Chemical Div. has opened a $600,000 synthetic-resin plant in Richmond, Calif. Automated, the facility makes 28 million lb./yr. of resins and adhesives, for captive manufacture into laminates and other wood products, foundry cores and molds, mineral wool. Autoclave is billed as one of the largest in the industry, makes 6,000-gal. pushbutton batches of resin.

The New Jersey Zinc Co. has begun construction of a multimillion-dollar electric furnace at Palmerton, Pa., in which iron-manganese ores from the firm's mine at Ogdensburg, N. J., will be smelted into spiegeleisen alloy. Due completed in 1962, project will insure "adequate supplies of spiegeleisen for many many years to come." Firm refuses to pin down specific capacity.

Kaiser Aluminum and Chemical Corp. has begun producing 99.99%-

TAKE A CLOSE LOOK AT ROCKWOOD BALL VALVES



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plus pure aluminum in five new electrolytic refining cells at Mead, Wash. Each cell turns out 380,000 lb./yr., thus tripling the firm's annual capacity at the site (to 5.3 million lb.).

Industrial Biochemicals, Inc., is on stream at Edison, N. J., with 4.5 million lb./yr. of new capacity for gluconic acid and sodium gluconate. Only such spray-dried product on the market, firm's sodium gluconate is made by "automated processing techniques permitted by novel fermentation innovation." Company refuses to elaborate.

Studebaker-Packard Corp.'s Onan Div. has joined the ranks of fuel-cell researchers with the opening of a technical center in Minneapolis, Minn. At the laboratory's dedication ceremonies, the automobile-manufacturing firm noted "the possibility that [fuel cells] could some day supplant internal combustion engines in automobiles."

Union Oil Co. of California has struck a new on-shore gas-condensate field at North Pagie Lake, 64 miles southwest of New Orleans. Multiple pay zones "of exceptional thickness" have been logged between depths of 11,000 and 14,800 ft., boosting Union's 4-trillion-cu. ft. of natural gas reserves by 25%.

Sylvania Electric Products Inc.'s Sylcor Div. has been awarded a contract by **Phillips Petroleum Co.'s** Atomic Energy Div. to fabricate slightly over 1,000 nuclear fuel elements and control rods. Described as the largest single contract ever awarded to private industry for the production of test-reactor nuclear fuel elements, the agreement specifies delivery of the aluminum-sheathed uranium components by February 1962. Units will be plugged into test reactors that Phillips operates for the AEC near Idaho Falls, Ida.

Linde Co., a division of Union Carbide Corp., has formally opened its 140-ton/day liquid-oxygen and

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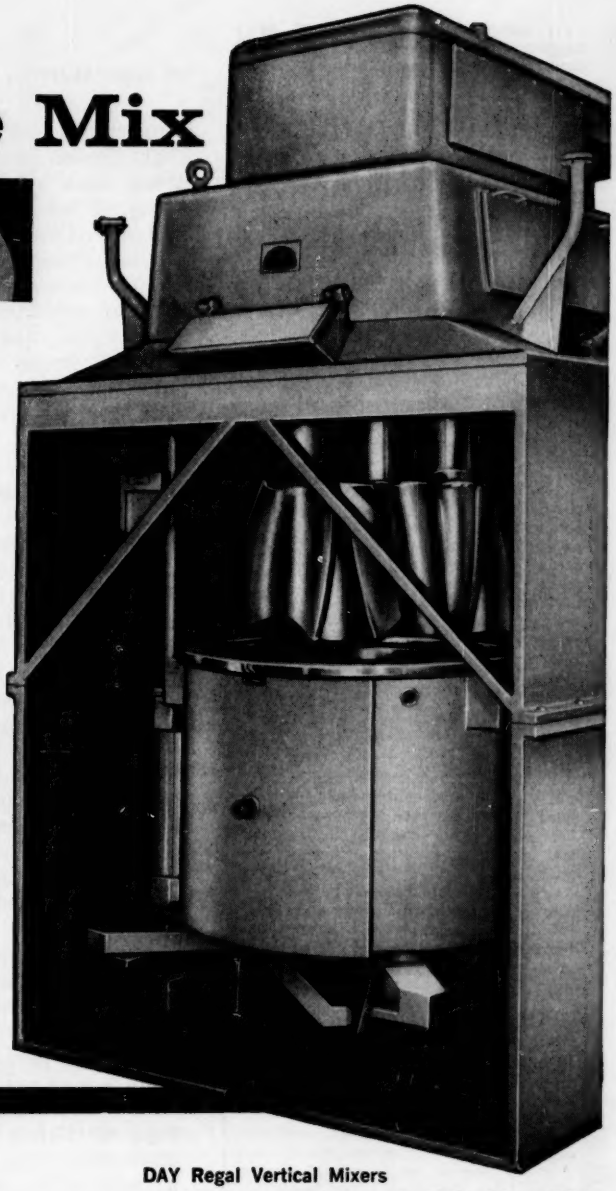

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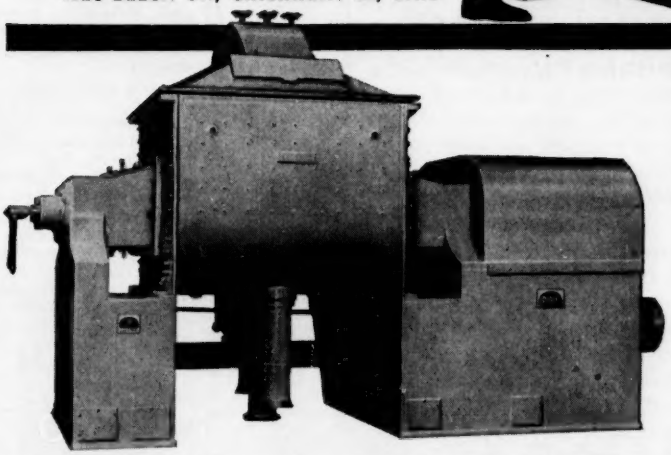

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. . . one of a series presented by Western Supply Company, Tulsa, to improve the "I.Q." of engineers . . .

MANAGEMENT STATUS: DREAM OR MIRAGE? TECHNOLOGY AN ASSET, OTHER TRAINING NEEDED

The complexity of modern industry has created a great demand for management personnel with engineering training. Surprisingly, there is a very short supply of such men, i.e., engineers with enough potential to be groomed for executive functions.

Historically, as big industry moved out of restricted, private ownership into broader public ownership, two things happened, both of which added to the demand for "management men." First, public ownership made possible more diversified management, as opposed to the centralized control characteristic of family ownership. Second, the complications and diversification of modern industry have sharply increased the ratio of executives to employees. Where the ratio was formerly approximately one executive to 100 employees, it is now more like one to 35.

Recognizing that employment has increased by about one-third during the same period, the need for management personnel becomes clearer. Not only do few engineers graduate from school ready to be managers, few of us study courses as undergraduates which would prepare us for executive leadership later in our careers. Finally, as a prerequisite for managing the affairs of others, there is no substitute for experience.

WHAT DO YOU REALLY WANT?

If you are facing this important decision in your present status, get your future into focus before taking the step. Decide what you really want from your personal and business careers. It is sometimes too easily assumed that all men want to move on to higher, executive positions. With few exceptions, all men pay lip service to "wanting to get ahead," but too many of us hoodwink ourselves into believing this means management responsibilities, without fully recognizing the significance of such a step.

As a matter of fact, all men *don't* want to advance into management. Some, however, find this out too late, for unless they are psychologically and emotionally suited for the rigors of management, the driving ambition to assume more leadership, responsibility and authority may not in itself be a worthwhile goal. If a man is doing well where he is, it may be a mistake for him to try to move into the management orbit, for the move to management is not the only door to advancement.

FOOTNOTE: These are only the first few paragraphs of Western's latest "professional advancement" series, Booklet E-9. Titled "Engineering-Management Status: Dream or Mirage?" your copy is free upon request. Write to Western Supply Company, Heat Exchanger Division, P. O. Box 1888, Tulsa, Okla. — **where your advancement is to our benefit and where the right decisions produce quality-design heat exchangers.**

CPI NEWS BRIEFS . . .

nitrogen plant at Marshall Space Flight Center, Huntsville, Ala. On stream since last fall, installation is one of five separators built to produce fuel for National Aeronautics and Space Administration's rockets. Linde's two other oxygen-nitrogen units operate at Pittsburg, Calif., and Neosho, Mo.; while a hydrogen installation is on stream at Torrance, Calif., and another is on the drawing boards for Fontana, Calif.

Susquehanna-Western, Inc., a subsidiary of The Susquehanna Corp., has a 250-ton/day uranium processing plant on stream near Falls City, Tex. Built at a cost of $2 million, unit is the firm's third (others are at Riverton, Wyo., and Edgemont, S. D.). Product—"yellow cake" concentrate—goes to the AEC under a $13-million contract.

Mobay Chemical Co., a joint subsidiary of Monsanto Chemical Co. and Farbenfabriken Bayer A.G., plans an additional 10-million-lb./yr. hike in its capacity for toluene diisocyanate (TDI) at New Martinsville, W. Va. Currently, a 15-million-lb./yr. expansion is under way (and due on stream later this month), which alone brings TDI potential at the site to 40 million lb./yr. The new construction will begin as soon as current work ends.

Reynolds Metals Co.'s alloys plant at Sheffield, Ala., is scheduled for a $2.5-million expansion. New facilities will include two 80,000-lb. batch holding furnaces and a pair of 100,000-lb. melting ovens. Latter are said to have a melt rate three times higher than Reynolds' present furnaces.

General Aniline & Film Corp.'s Antara Div. will boost its capacity for chlorine and caustic soda at Linden, N. J., by almost 500%. Due on stream early in 1963, multimillion-dollar expansion will bring present 50-ton/day production up to 230 tons/day.

Procter & Gamble Co. has earmarked $4 million to build a synthetic detergent plant in Augusta,

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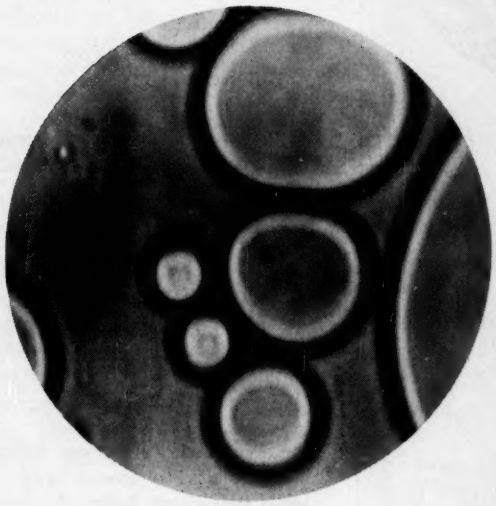

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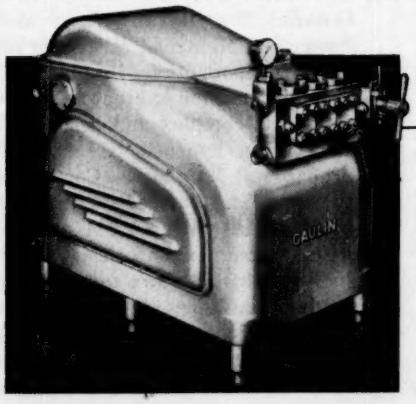

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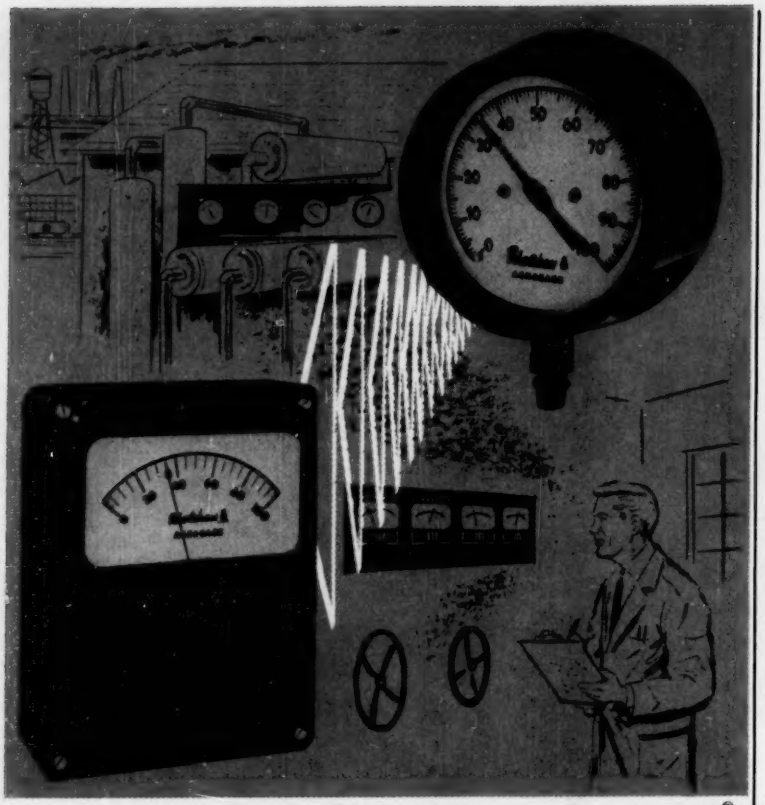

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CPI NEWS BRIEFS . . .

Ga. Half a dozen packaged powders will be made on the 283-acre site when facilities come on stream early in 1963.

Companies

Beryllium Metals & Chemicals Corp. has jointly been created by Lithium Corp. of America and The Alloyd Corp. New firm will "engage in beryllium research and in the purification and production of beryllium metals and chemicals" in a plant proposed for Bessemer City, N. C., next door to Lithium Corp.'s existing reduction facilities.

The Western Petroleum Refiners Assn. wants to merge with **National Petroleum Assn.** Product of the merger would be called National Petroleum Refiners Assn., the bylaws and legal paper of which are currently being drawn up.

Inert Gas, Inc., has been created in Houston to manufacture and rent portable inert-gas generators that produce a mixture of N_2, CO_2 and A for purging and blanketing explosive gases and toxic fumes that may be found in process equipment and plant areas.

International

Canada: Shawinigan Water and Power Co., Montreal, reveals in its annual report that it plans to spend $65 million to create a petrochemicals complex and associated 125,000-kw. hydroelectric station, probably at Rapide des Coeurs on the upper St. Maurice River. Power plant alone will cost $44 million, go on stream about three and a half years from now; construction begins this summer. Details on the petrochemicals complex are being withheld, but appear to be entirely in the hands of the power com-

pany's chemicals subsidiary, Shawinigan Chemicals Ltd.

Sweden's first polyethylene plant will be a 35-million-lb./yr. unit near Gothenburg, jointly planned by Superfosfat Fabriks Aktiebolag, Stockholm, and Union Carbide Corp., New York. Due on stream in 1962, facility will make the country self-sufficient in polyethylene.

Czechoslovakia, East Germany, Poland and Rumania have all bought the high-pressure polyethylene route of Imperial Chemical Industries, Ltd. The simultaneous $19.6-million, four-nation deal was arranged by Simon-Carves, Ltd. (a member of the Simon Engineering Group of London), which will construct and initially operate the proposed plants behind the Iron Curtain.

Sweden: Svenska Esso A.B., an affiliate of Standard Oil Co. of New Jersey, has awarded The Fluor Corp., Ltd., a $15-million contract for a steam-cracking plant at Esso's petrochemical project in Stenungsund. Construction will begin late this summer, with completion scheduled for early 1963.

Great Britain: Courtaulds Ltd. will make monochloroacetic acid and sodium monochloroacetate in a unit scheduled for summer construction and early-1962 completion at British Celanese Ltd.'s complex in Spondon. Details of the continuous, high-yield route haven't been disclosed, but production is scheduled to meet both the total domestic demand and some export quotas as well. Currently, neither chemical is made in the country.

Argentina: Hydrocarbon-Argentina, S.A., Buenos Aires, has been created by Hydrocarbon Research, Inc., New York, and Minera Alumine, S.A., Buenos Aires, to build and operate a $15-million refinery at San Lorenzo, Santa Fe Province. Hydrocarbon Research's HDA hydrodealkylation process will feed on naphtha stock from

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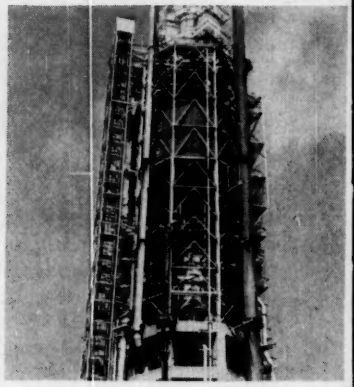

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Special hot-dip aluminum-coated Armco Steel enables you to cut first cost and reduce maintenance expense of weather shields and insulation jacketing for reactors, drums, processing towers, boilers and piping.

Armco ALUMINIZED STEEL Type 2 combines the surface qualities of aluminum with the strength and economy of steel. It not only meets requirements of strength and corrosion resistance, but cuts costs as well.

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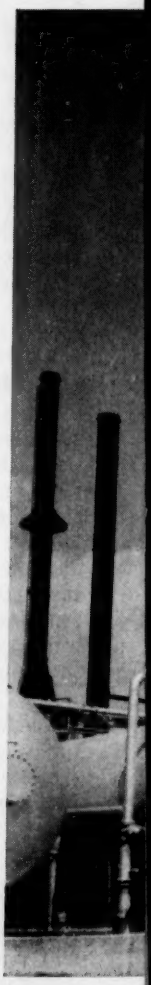

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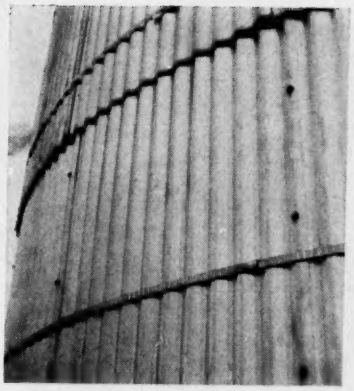
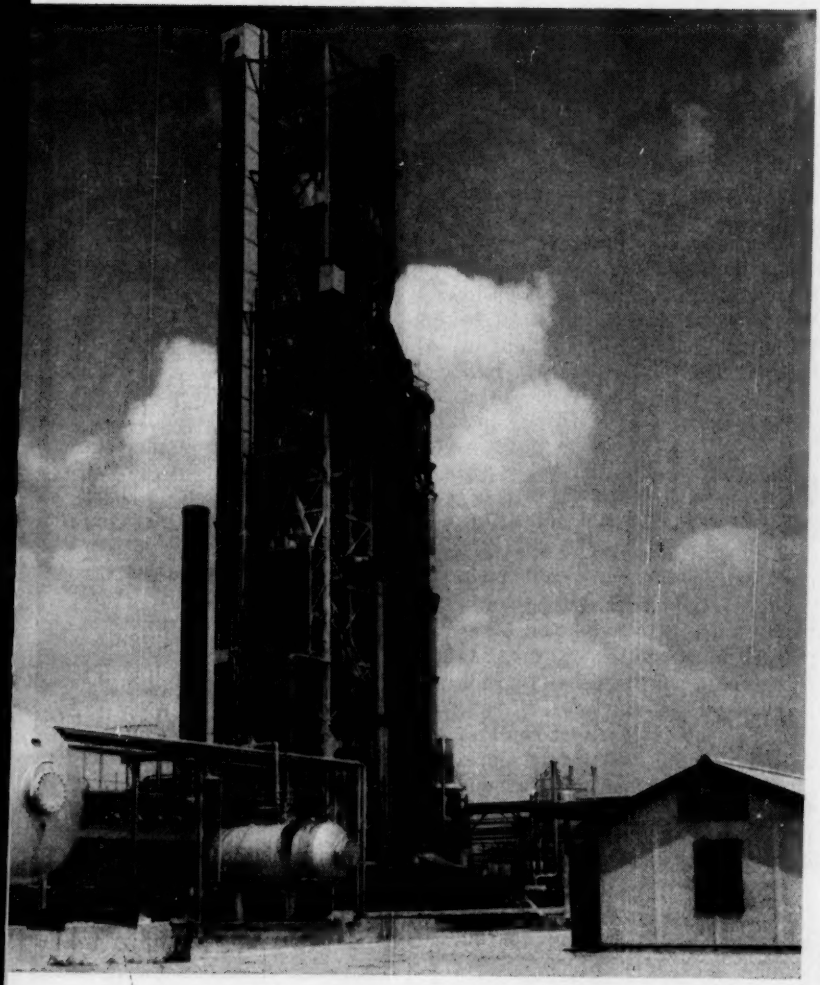


ALUMINIZED STEEL Type 2



CPI NEWS BRIEFS . . .

two nearby state petroleum refineries, turn out 60,000 tons/yr. of benzene; 8-11,000 bbl./day of high-octane gasoline; lesser amounts of toluene and xylenes. Benzene production will make the country self-sufficient in that petrochemical.

Italy: Dow Chemical International Ltd. S.A. has awarded Foster Wheeler Italiana of Milan the construction contract for a 16,000-ton/yr. polystyrene plant in Leghorn. Installation is due on stream in mid-1962.

Sweden: SKF Hofors is spending $15 million to install an acid open-hearth furnace with a capacity of 90,000 tons/yr.—said to be the country's largest—at its Hofors works in central Sweden. Facility's crude-steel capacity is hiked to 290,000 tons/yr. by the move. Most of the steel is to be captively manufactured into ball-bearing tubes.

Bulgaria: A petrochemical center is planned by U.S.S.R. engineers for Bugas, Bulgaria. Due on stream by mid-1963, initial units of the project will be a 2-million-metric ton/yr. refinery and 10,000-metric ton/yr. polyethylene unit. Tass announced the move as heralding "emergence of an entirely new industry."

Switzerland: American Cyanamid Co.'s $1.7-million, Cyanamid European Research Institute has formally been opened at Colgny, three miles north of Geneva. New center is devoted to basic research by 60 European theoreticians in high polymers, solid-state physics, organic and inorganic chemistry.

Mexico: Carborundum Mexicana S.A., a subsidiary of Carborundum Co., plans a $1.5-million abrasives plant in Toluca, near Mexico City. Due on stream late this year, facility will turn out bonded abrasives for hones, grinders; and coated abrasives for belts, disks.

Netherlands: Esso Nederland N.V., Dutch affiliate of Standard Oil Co. (New Jersey), plans a $17-million petrochemicals plant near

Highly Intimate Blends in 1 to 2 Minutes

Blends while discharging; No segregation or flotation

Sturtevant Rotary Blenders start 4-way blending while charging, continue it during discharge, thus producing highly intimate, even blends of dry and semi-dry materials – within 3 to 5 minutes of start of charging.

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Receiving

Scoops cascade material as drum rotates. Movement forces material from both ends to middle. Thus blending is 4-way right from start of charging.

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Single gate controls charge, discharge. Blending continues throughout discharge phase. Result is no segregation or flotation — highly intimate, even blends.

Self-cleaning, dust-sealed drum; one-man accessibility

Operation of Sturtevant Blenders is self-cleaning – drum interiors are completely dust-sealed. For inspection of all models, one man simply loosens a few lugs to remove manhole cover – quickly and easily.

Nine standard models with capacities to 900 cu. ft.

10 cu. ft. Sturtevant Blender at U.S. Steel Corp.'s new Applied Research Laboratory (Raw Materials Division) in Monroeville, Pa. This unit handles batches up to 500 lbs. — is ideal for pilot work and small runs.

One of four 450 cu. ft. Sturtevant Blenders at Celriver Plant of Celanese Corp. (Rock Hill, N. C.). These large units handle up to 20,000 lbs. batches — have a 9-year record of meeting the most exacting blending requirements.

Fully or semi-automatic, or manually controlled operation

Constructed of carbon steel, stainless steel or Monel metal, Sturtevant Rotary Blenders are engineered to fit each customer's needs – can be supplied with injector sprays and any desired control system.

For more on Sturtevant Blenders, request Bulletin No. 080B. (Bulletins also available on Mixers, Air Separators, Micronizers, Crushers and Grinders.) Write today. STURTEVANT MILL CO., 100 Clayton St., Boston, Mass.

CPI NEWS BRIEFS . . .

Rotterdam. Due on stream by 1963, the 220,000-metric ton/yr. facility will produce benzene, toluene, xylene and xylene derivatives.

Great Britain: Fisons Ltd. and Esso Petroleum Co. Ltd. plan to create a new, as-yet unnamed company to make 150,000 long tons/yr. of ammonia in a proposed $11.2-million plant adjacent to Esso's refinery in Milford Haven, Pembrokeshire. Representing a 20% boost of Great Britain's current ammonia capacity (most of which comes from Imperial Chemical Industries, Ltd.), new production would be piped to a nearby plant that Fisons plans to build, and wholly own, where the ammonia will be converted to fertilizer and other nitrogen products. Both units are due on stream by the spring of 1964.

Simultaneously, Fisons announced the planned doubling of its nitrogen capacity at Flixborough, Lincolnshire. To cost $22.4 million, nitrogen expansion would also come on stream in 1964.

Brazil: Fongra Produtos Quimicos, a subsidiary of West Germany's Farbwerke Hoechst A.G., plans to boost output of caustic soda to 2.5 million tons/yr. at its plant in Suzane, Sao Paulo. Over $1 million in new capital had to be raised for the move.

Israel: Electrochemical Industries, Acre, plans a $3-million, 10-ton/day mono- and polyvinyl chloride facility on Haifa Bay. Announcement closely follows Israel Petrochemical Industries Ltd.'s statement of intent to build four other petrochemical units on the bay (ethylene, polyethylene, carbon black, detergent alkylate), all to be fed by the recently completed 257-mi. pipeline that safely routes 2 million tons/yr. of crude around the troubled Suez Canal, from Eilat on the Red Sea to Haifa on the Mediterranean.

Canada: Carstairs Operators' Committee plans to expand its 70-million-cu. ft./day gas-processing

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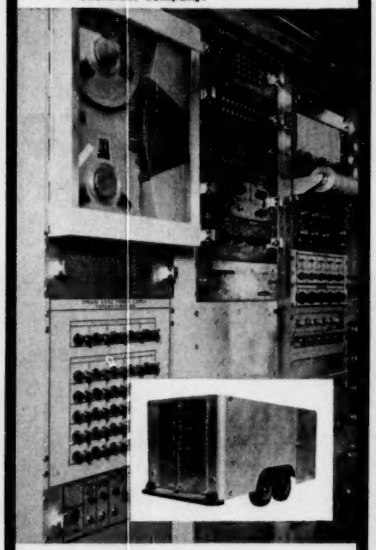

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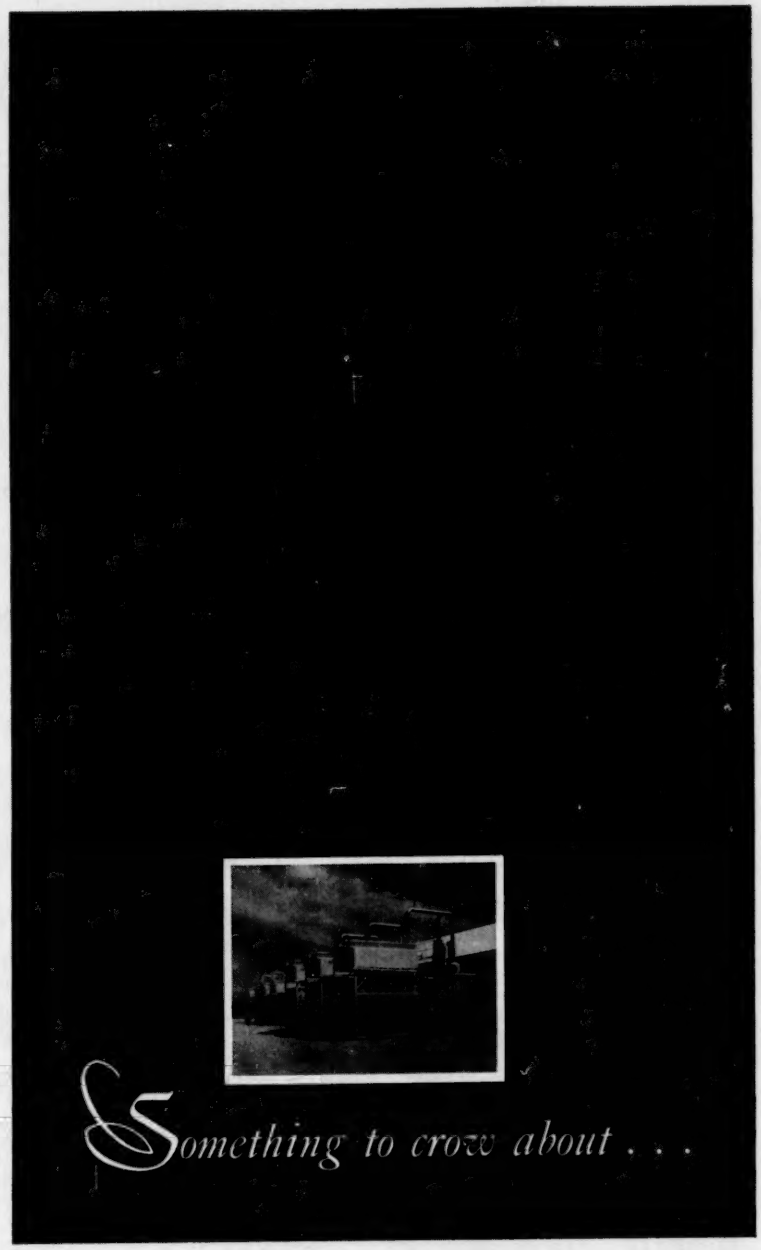
plant in Carstairs, Alta., by almost 200%. The Fluor Corp. of Canada, Ltd., has a $3-million contract to engineer and construct the new facilities, which will include an ancillary unit to recover liquid hydrocarbons from the gas stream. New total capacity will be 200 million cu. ft./day of sales gas, due on stream this November.

West Germany: Farbenfabriken Bayer A.G., Leverkusen, has placed an electrolytic chlorine plant on stream at Uerdingen. Installation's 30,000-ton/yr. capacity is scheduled for a two-stage expansion: first step will boost output by 50% (and is already under construction); second will hike capacity to a total 60,000 tons/yr. Bayer currently makes some 170,000 tons of chlorine at various sites in the country.

Canada: Multi-chem Products Ltd. has been created by British America Paint Co., Ltd., Victoria, B. C., and Chemical Oil and Resin Co., Toronto (itself a subsidiary of Ault & Wiborg Co. of Canada Ltd.). New firm will produce an undisclosed tonnage of polyester resins in a "special building" at British America Paint's inner-harbor plantsite at Victoria.

Morocco has awarded construction contracts for its $50-million chemicals complex at Safi, port city on the Atlantic. The West German firm Lurgi-Gesellschaft fuer Waermetechnik will build a 400,000-ton/yr. sulfuric acid unit; U.S.'s Dorr-Oliver Inc. will construct a companion, 150,000-ton/yr. phosphoric acid plant; and Krebbs of France will erect a 200,000-ton/yr. triple-superphosphate facility. Construction begins in July.

Italy: Bombrini Parodi-Delfino S.p.A. plans to have a 10-million-lb./yr. maleic anhydride plant on stream by mid-1962 at Colleferro. Now being engineered by Scientific Design Co., Inc., unit will use the SD air-oxidation of benzene route. Bombrini principally manufactures explosives, but recently has branched out into nylon-6, phthalic anhydride, and detergents.



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Convention Calendar

June

19-21. University of Southern California, Heat Transfer and Fluid Mechanics Institute, Los Angeles, Calif.

19-23. Massachusetts Institute of Technology, Technology of Reinforced Plastics Course, Cambridge, Mass.

19-30. The University of Michigan, Engineering Summer Conference on Systems Engineering, Ann Arbor, Mich.

20-26. European Federation of Chemical Engineering, Third Congress, London, England.

21-1. Interplas 61. Sixth International Plastics Exhibition and Convention, Olympia, London, England.

21-23. American Assn. of Cost Engineers, Annual Meeting, Somerset Hotel, Boston, Mass.

22-25. Society of Women Engineers, National Convention, Statler-Hilton Hotel, Boston, Mass.

23-25. Compressed Gas Assn., Inc., 48th Annual Meeting, Waldorf-Astoria Hotel, New York, N. Y.

25-30. American Society for Testing Materials, Annual Meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

26-30. American Society for Engineering Education, Annual Meeting, University of Kentucky, Lexington, Ky.

26-7. Massachusetts Institute of Technology, Summer Program on Dynamics and Control of Chemical Engineering Processes, Cambridge, Mass.

28-30. American Institute of Chemical Engineers, Instrument Society of America, American Institute of Electrical Engineers, American Society of Mechanical Engineers, Institute of Radio Engineers, Joint Automatic Control Conference, University of Colorado, Boulder, Colo.

July

3-7. Gordon Research Conference, Polymers, Colby Junior College, New London, N. H.

4-7. National Society of Professional Engineers, Annual Meeting, Olympic Hotel, Seattle, Wash.

10-14. Society of the Chemical Industry, Annual Meeting, Oxford, England.

10-14. Colorado State University, Fourth Annual Institute in Technical and Industrial Communications, Fort Collins, Colo.

10-29. Case Institute of Technology, Process Control Theory Course, Cleveland, Ohio.

17-21. National Assn. of Power Engineers, National Convention, Sheraton-Gibson Hotel, Cincinnati, Ohio.

17-21. Gordon Research Conference, Organic Coatings, Kimball Union Academy, Meriden, N. H.

18-20. Western Plant Maintenance and Engineering Show, Pan Pacific Auditorium, Los Angeles, Calif.

24-28. Gordon Research Conferences, Corrosion-Oxidation of Metal Surfaces, Colby Junior College, New London, N. H.

31-11. Case Institute of Technology, Digital Control Systems Course, Cleveland, Ohio.

August

3-5. Chemical Institute of Canada, Annual Conference and Exhibition, Queen Elizabeth Hotel, Montreal, Que.

7-11. Gordon Research Conferences, Separation and Purification, Colby Junior College, New London, N. H.

7-11. Gordon Research Conference, Statistics in Chemistry and Chemical Engineering, New Hampton School, New Hampton, N. H.

14-17. Louisiana State University, Ninth Annual Short Course in Fundamentals of Occupational Safety, Baton Rouge, La.

14-18. Gordon Research Conference, Instrumentation, Colby Junior College, New London, N. H.

15-17. University of Michigan, Cryogenic Engineering Conference, Ann Arbor, Mich.

15-18. Technical Assn. of the Pulp and Paper Industry, Testing Conference, Queen Elizabeth Hotel, Montreal, Que.

Later

September 3-8. American Chemical Society, National Meeting, Chicago, Ill.

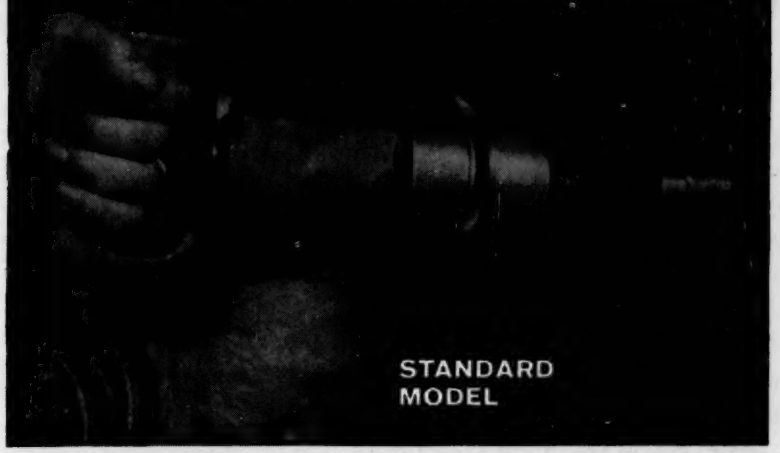
September 24-27. American Institute of Chemical Engineers, National Meeting, Lake Placid, N. Y.

October 11-12. CHEMICAL ENGINEERING and Armour Research Foundation, Conference on the New Trends in Chemistry, Sheraton Towers Hotel, Chicago, Ill.

November 27-December 1. 28th Exposition of the Chemical Industries, New York Coliseum, New York, N. Y.

ELLIOTT air magnetic tube expander drives

automatically controlled for fast, accurate tube rolling



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Elliott Tube Gage

Y1-2

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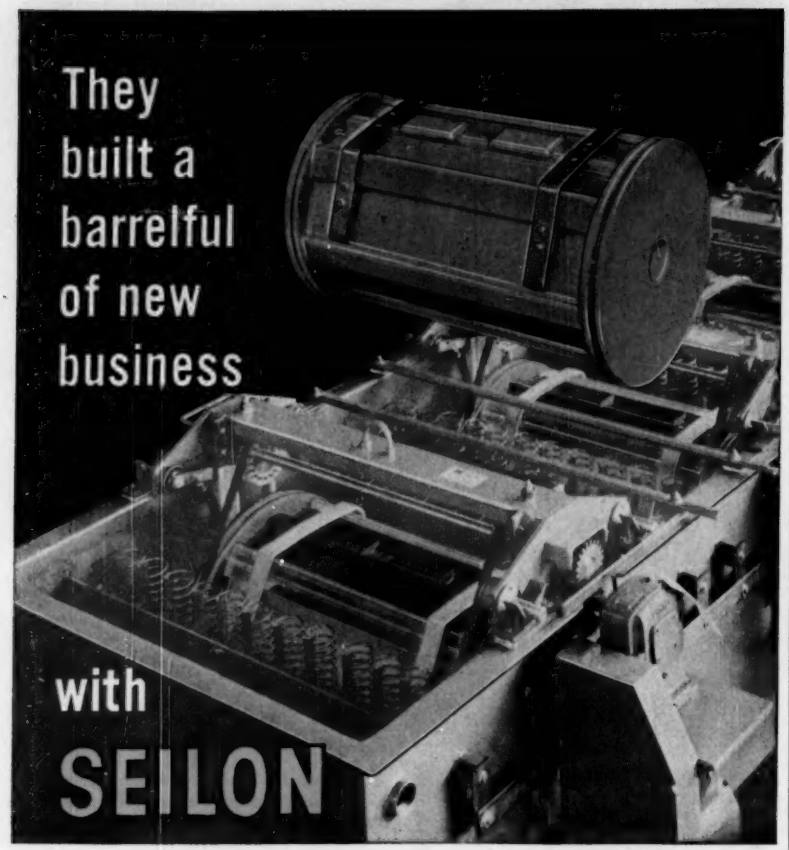

WHEN YOU DUMP A LOAD OF 2" BOLTS (or any other heavy parts) into a plating barrel, you had better know what you're doing. Breakage of barrels due to careless loading has long been a problem in the plating industry.

Seiberling technicians recognized this fact, and determined that SEILON PRO, a practically indestructible polypropylene, would be a far superior material to use for the barrels. Seiberling recommended SEILON PRO to the G-S Equipment Company of Cleveland, a manufacturer of replacement plating barrels.

THE RESULT: NEW CUSTOMERS AND A BOOMING BUSINESS! Seiberling provided G-S with technical instruction in handling and hot-welding SEILON PRO. The new barrels, with their remarkable resistance to heat, abrasion, and impact, gained immediate industry acceptance. "In just seven months, our business has grown considerably," says Thomas W. Gulley, Jr., Vice President of G-S. "We attribute this growth, in large part, to Seiberling's superior material and technical competence."

SEILON is versatile in its many properties and tailor-made adaptability to your requirements. We welcome the opportunity to help solve your problems—a letter or phone call will start us working.

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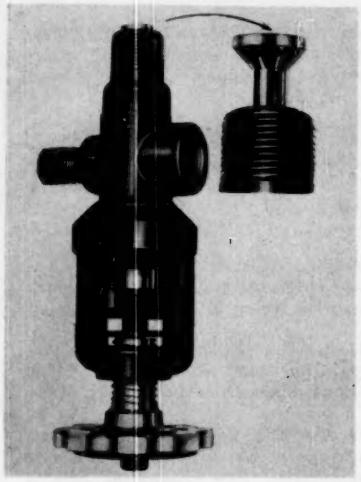
NEW EQUIPMENT . . .

(Continued from page 118)

hydraulic operation. The body is offered in any commercially available elastomer, such as gum rubber, Neoprene, butyl rubber and Hypalon. Body flanges are protected by full elastomer facings.— **RKL Controls, Inc., Hainesport, N. J.** **118D**



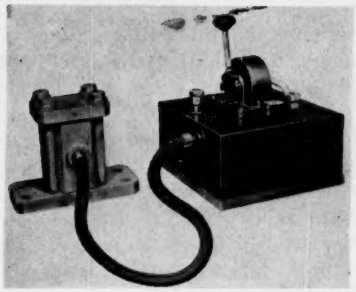
Self-draining valve

Valve seat, inside wall of pipe or vessel, excludes liquid.

Liquid can't remain in the body of this self-draining valve after it is closed because the valve stem is seated on the outside of the body. The inlet can't plug with material, either, since the stem lifts up into the tank or pipe when the valve is opened, pushing any sediment off the opening.

The threaded portion of the stem, outside the valve body, is not affected by the temperature or nature of the liquid being handled. The portion of the stem inside the body operates in a straight-line motion with no rotating action, preserving the valve seat from galling upon closing.

Unit has 1-in. tank connection, ¾-in. drain connection, and ½-in. plugged purge connection. Standard valve has carbon steel body, stainless steel stem. — **Jerguson Gage and Valve Co., Burlington, Mass.** **290A**

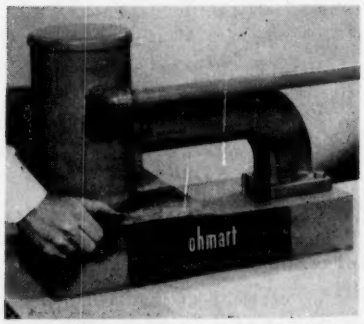


Pneumatic vibrator

Control adapter regulates unit's frequency and impact force.

Impact and frequency of this pneumatic vibrator are controlled by an attachment known as an impact-frequency adapter. Connected to the vibrator with a flexible hose, the adapter closely controls the input of compressed air to give the most-efficient vibrations for flow of materials or control of equipment on which the vibrator is used.

Flange-mounted, the lightweight unit starts and stops with only 3-psi. line pressure. Rubber shock absorbers under each bolt head prevent the bolts from stretching, and a safety clip keeps them from vibrating loose. Unit comes in 1¼ and 3-in. sizes, with vibration range up to about 6,000 vib./min.—**The Branford Co., New Britain, Conn.** 291A



Thickness gage

Compact unit, using beta radiation, handles sheet material 12-in. wide.

For laboratory and pilot-plant operations, a small-size nuclear thickness gage can be used to de-

NEW BARTON 273 PNEUMATIC TRANSMITTER MEETS MORE APPLICATION REQUIREMENTS THAN ANY OTHER TRANSMITTER

The Barton 273 offers the widest differential pressure ranges (0-8″ w.c. to 0-400 psi), the highest safe working pressures (to 10,000 psi), and the widest variety of housing materials (aluminum, brass, steel, 316 stainless steel). It's compact, weighing up to less than ½ the weight of other units. It has adjustable suppression up to 80% of DP range, and adjustable span. A non-bleed relay minimizes air consumption. It doesn't shift zero on overrange. It's unaffected by normal piping stress. In every respect, the Barton 273 is the most significant advance in pneumatic transmitters in the past decade. There's a lot more you should know about it—for complete data write

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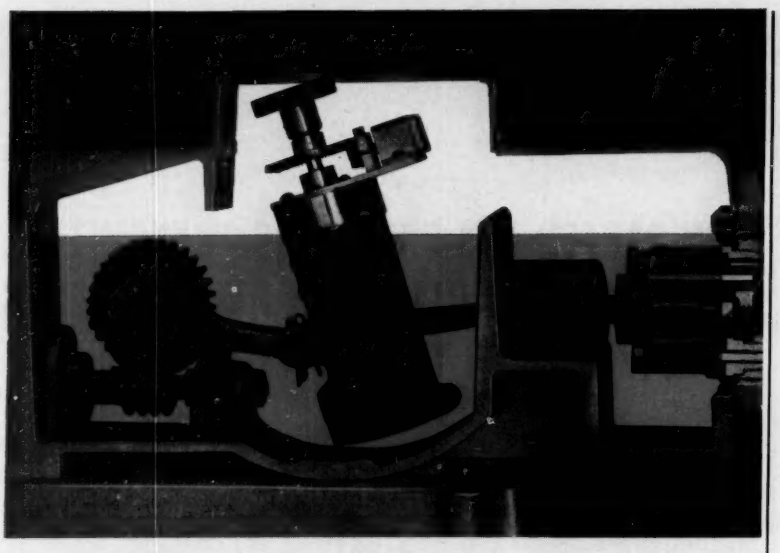
termine the thickness or density of plastic films, paper, coated materials, rubber, glass, floor coverings and metal foils.

Depending on the radiation source, the gage can measure thicknesses as small as 0.002 in., with repeatability ±2% of scale or better. Krypton 85 is used as a source for very thin materials, strontium 90 for thicker ones.

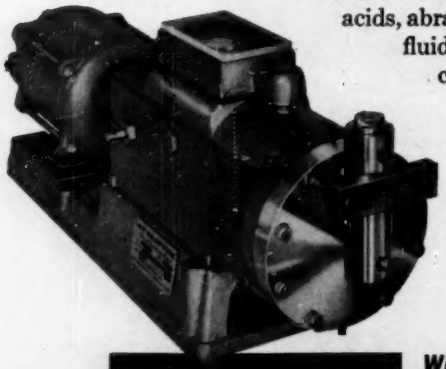
Operating principal is the same as that used in production-size gages by the same manufacturer: the amount of transmitted beta radiation that passes through the material being measured is monitored by a cell whose electrical output is altered by changes in the radiation that reaches it. — **The Ohmart Corp., Cincinnati. 291B**



This is why you never heard of a PULSAFEEDER wearing out!

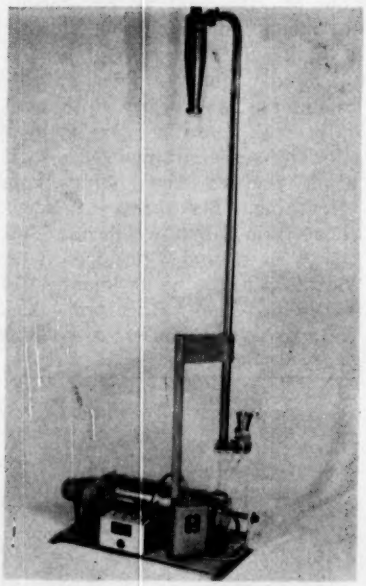
Every moving part of every Lapp Pulsafeeder Metering Pump is completely submerged in oil. This total lubrication reduces friction to practically the theoretical minimum. And there's no possibility of corrosion from exposure to atmosphere.

For year after year of *extra* service life, Lapp Pulsafeeders continue to give you the exclusive advantages for which you bought them. Advantages like complete freedom from leakage and contamination; precision metering, at flow rates from a few drops to 15.7 gallons per minute; pressures up to 7000 psig; choice of heads for safe handling of acids, abrasive slurries, radioactive fluids; manual or instrument controls, We've got a new catalog to help you fit the right model to your process.



Lapp

***WRITE** for Catalog 59. Lapp Insulator Co., Inc., Process Equipment Division, 1118 Poplar Street, LeRoy, N. Y.*



Pilot flash-dryer

Pneumatic unit facilitates study of rapid flash-drying methods.

A vertical pneumatic dryer makes it easy to investigate flash drying and fluid-bed operations on bench or pilot scale, in preparation for scaleup. It can also be used to prepare samples and small production quantities of experimental materials.

Called the V-P Drier, the unit will handle from 5 to 20 lb./hr. of

Shell has three benzene-producing refineries, located near waterways. Barges like these will carry the bulk of 1961's record output.

BULLETIN:

Shell has increased benzene production to meet your rising needs— capacity now exceeds 80 million gallons

Shell has increased its benzene production nearly 500 percent in less than 18 months. Shell's benzene-producing capacity in the U. S. is now the largest in the world.

Shell's stepped-up output comes to you via a nationwide supply network served by 3 refineries.

Read how Shell's increased benzene production can help you meet your rising benzene requirements now.

WITH DEMAND for benzene at an all-time high, and with new uses coming along each year, Shell is producing more benzene now than ever before.

Bigger supplies now

Shell has stepped up production of benzene again. Shell's capacity has already topped 80 million gallons of high purity benzene. *And Shell has nationwide facilities for producing and distributing benzene.*

Widest distribution

Shell Benzene is produced at three refineries. At Wood River, Illinois; Houston, Texas; and Wilmington, California.

NOTE: All three refineries are located near waterways. You can take delivery of Shell Benzene in barges, in tank cars and transport trucks. Deliveries can come direct from the refinery.

Formulators use Shell Benzene when precise control is vital. The quality of Shell Benzene is consistently high.

And it is free of Thiophene.

For full facts on Shell Benzene, contact your Shell Industrial Products Representative. Or write: Shell Oil Company, 50 West 50th Street, New York 20, N. Y.

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ROTOR LIFT is the *original* enclosed screw elevator; and since its introduction in the '20s, research engineering has kept it the *finest*, with such features as:

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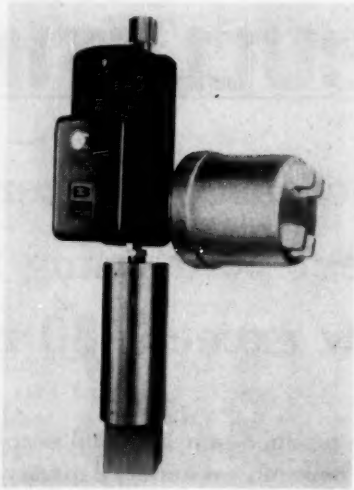
feed material, evaporating 5-7 lb./hr. of moisture. With electrical heat, drying temperature ranges from ambient to 800 F., at velocities up to 6,000 ft./min. For high-temperature operation, a gas heater boosts drying temperature to 1,500 F., with gas velocities at the feed point possible up to 20,000 ft./min. The 10-ft. dryer may be equipped with either gas or electric heating, or both.

Fluid-bed systems may be incorporated into the unit by removal of the vertical drying sections. For special studies, recycle of dried products is possible, using a timed solids splitter and a variable screw feeder.—**Bench Scale Equipment Co., Westfield, N. J.** 292A



High-pressure rotameter

Unit gives direct measurement of flows at up to 50,000 psi.

Liquids flowing at up to 50,000 psi. are directly measured by a rotameter, incorporating a magnetic position converter that translates float position to an output signal that is linear with flow rate.

Rated at 0.9 to 47-gpm. capacity in four sizes, the rotameter has an integral pulsation-damping device that smooths out cyclic or intermittent flow surges to maintain a relatively straight-line readout.

For higher flow capacities, meter may be installed in a bypass,

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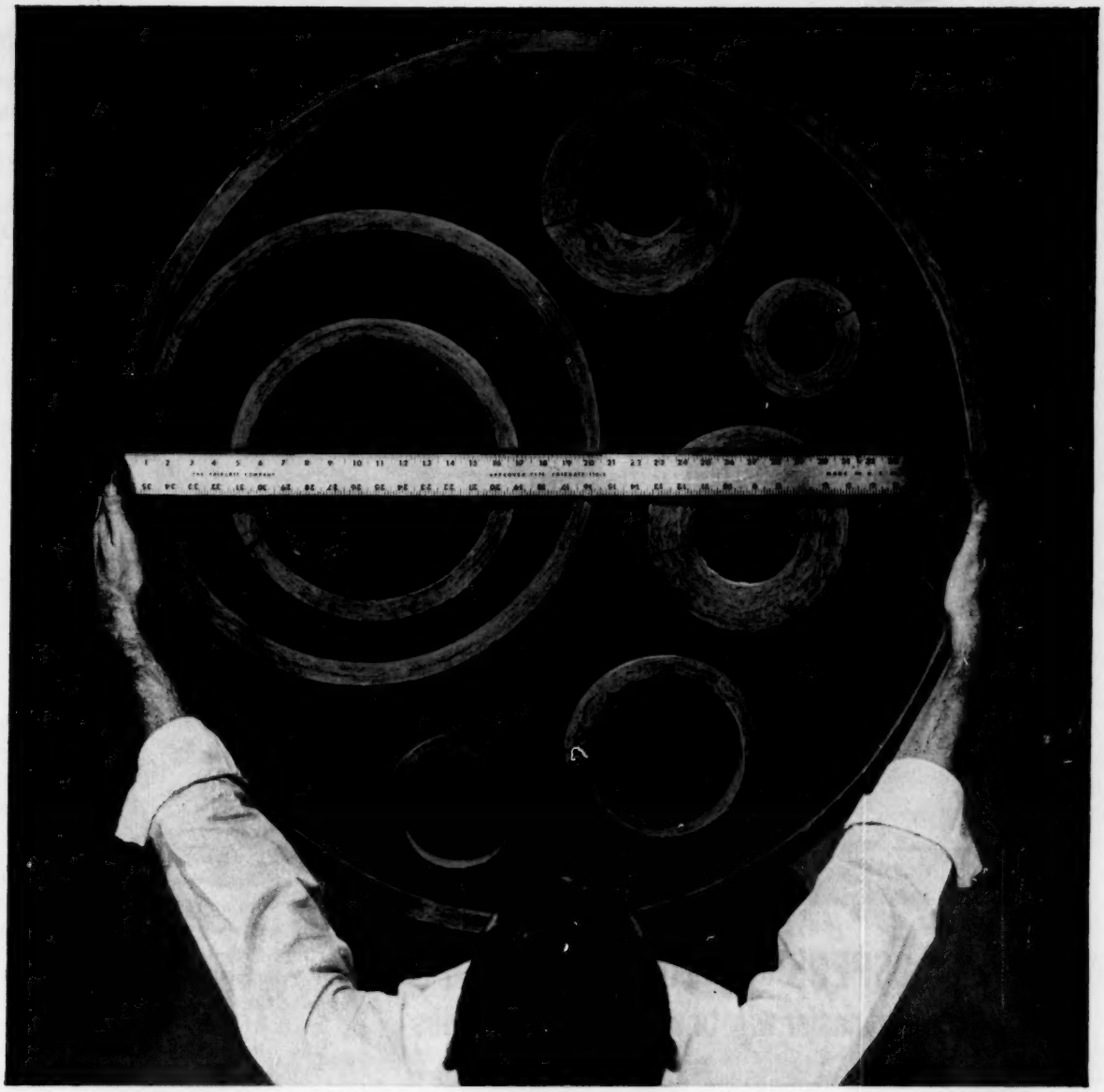

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Only G-B Snap*On offers you all the time-saving, cost-cutting advantages of a one-piece glass fiber pipe covering for pipe sizes from copper tubing all the way up to 36" IPS. With G-B Snap*On's snap-hinge action, you can cut installation time up to 50% on virtually every pipe insulating job—and even more on the larger pipe diameters. It's available in 3' sections, plain or with a wide variety of factory-adhered jackets for sub-zero to 350° F. piping—indoors or out, and in 6' sections without jackets.

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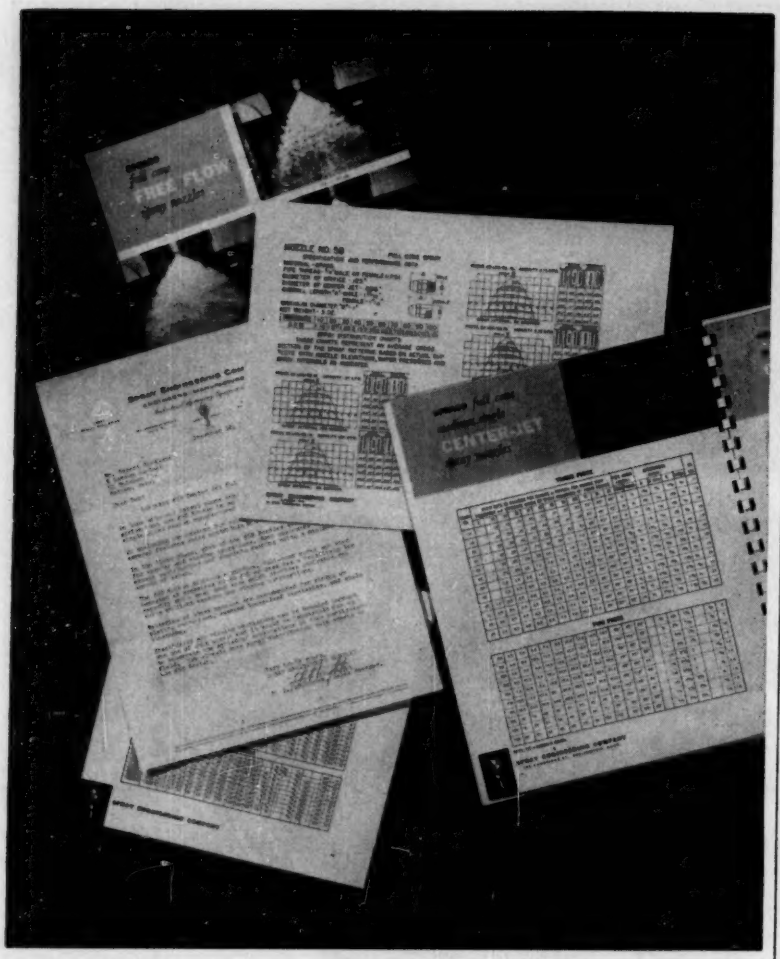

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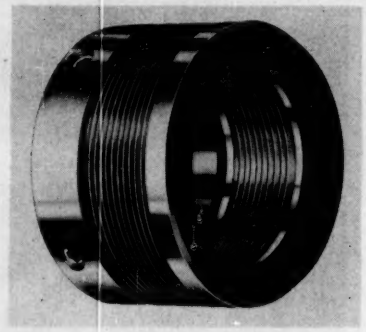
with an orifice plate in the main pipeline. For safety, rotameter bodies are one-piece forged, have no welded joints or connections.— **Brooks Instrument Co., Inc., Hatfield, Pa.** **294A**



Bellows seal

Rotating unit has extremely wide heat range —350 to +800 F.

Rotating on a carbon seal ring, a bellows seal will accommodate temperatures from cryogenic to 800 F. Heart of the seal is a welded, stainless steel bellows attached to a drive collar at one end, and a carbon retainer for the seal ring at the other end.

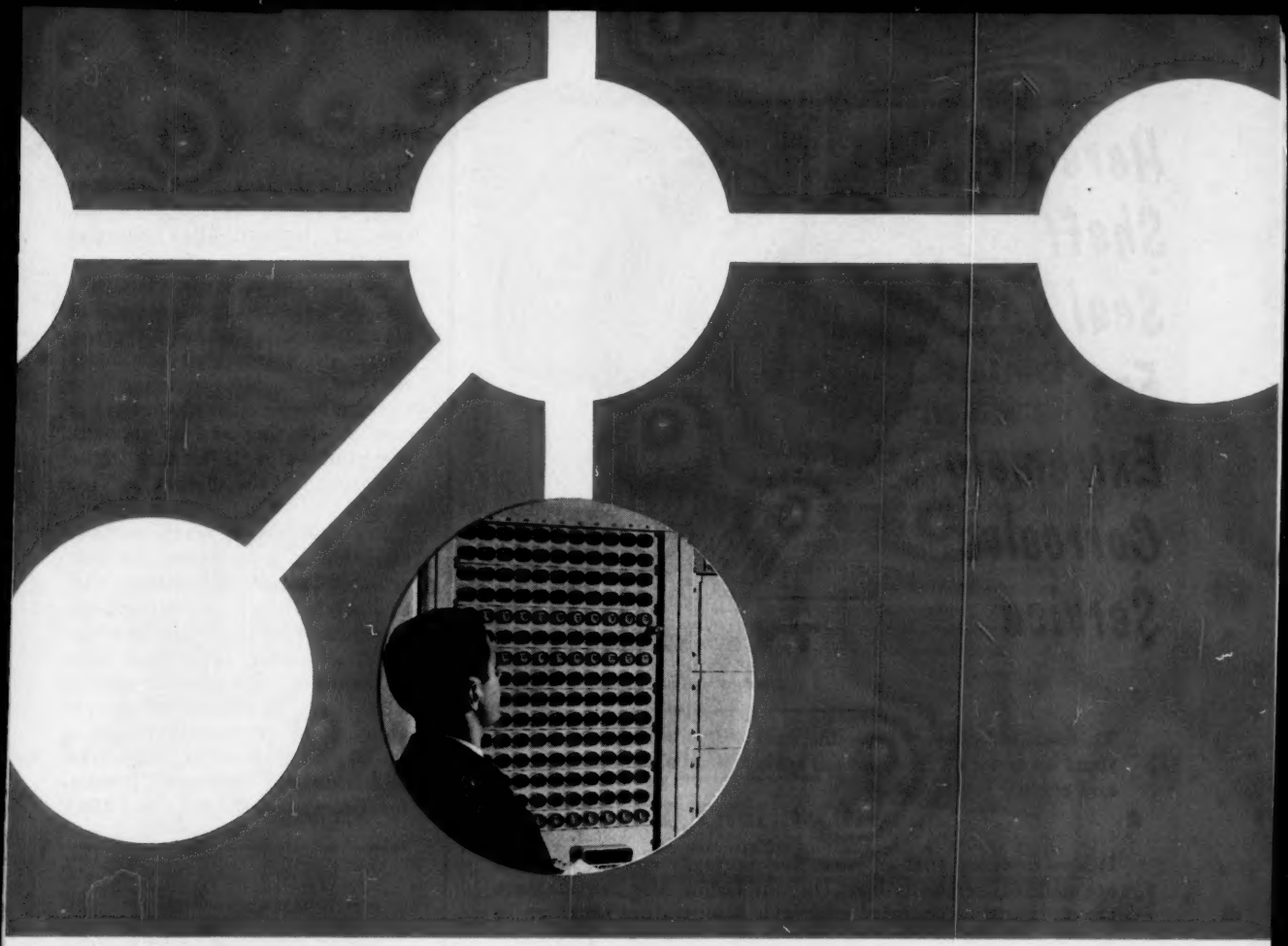
Previous rotating face-type seals have the carbon ring sealed to the shaft with an O-ring or other device that tolerates axial motion. This unit eliminates dynamic elastomers, sealing the drive collar to the shaft with a metallic gasket or an o-ring.

Standard units will accept pressure to 300 psi., without the need for sleeves or special steps cut into the shaft. — **Sealol, Inc., Providence, R. I.** **296A**

Temperature transmitter

Pneumatic unit is available with gas or mercury-filled systems.

A pneumatic temperature transmitter, either indicating or non-indicating, uses a filled thermal system and transmits a standard 3-15-psi. signal that varies in pro-



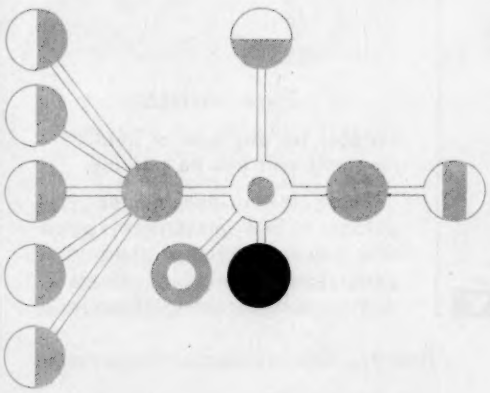
PROCESS PROTECTOR

Hagan AIM—centralized monitoring of all important variables

Temperatures, pressures, flows, levels, closures, in fact any input that can be represented by DC voltages as low as 10 millivolts full scale can be monitored by the Hagan AIM (Alarm Indicating Monitor) with an accuracy of plus or minus 0.1% full scale.

Fast and reliable, the Hagan AIM is compact—for example, the readout and alarm panel for 200 alarm points will fit into a 19″ x 47¼″ panel area. Combining all alarm functions in one instrument, AIM can be set for high or low alarm points, or both. Seconds after a monitored variable goes out of bounds, AIM energizes the alarm light and sounds a warning horn. The horn can be shut off, but the light stays lit until the condition is corrected. AIM safeguards both equipment and process from the shattering damage that a single runaway variable can produce. Now *one* man can watchdog a complete process line, taking corrective action before damage is done.

AIM is one component of the complete Hagan line of process controls, which include primary elements, transducers, controllers, recorders and final control elements. Designed for use with existing installations or for complete new systems, the Hagan line can save you money in terms of more accurate control with minimum adjustment and maintenance. For information, write or phone HAGAN CHEMICALS AND CONTROLS, INC., Hagan Center, Pittsburgh 30, Pa.



HAGAN

This seal is built to handle the most corrosive services. It will stand up under all conditions of acids and salts, oxidizing agents and organic compounds.

It is so designed that all parts that normally contact the fluid are made of chemically-inert DuPont Teflon. Also, for this same reason it can be operated over wide temperature range up to 250° F.

Mechanically, its bellows type construction readily adapts it for use in all non-abrasive slurry applications. It also compensates for extreme shaft run out.

Available in single face construction for internal or external mounting, double face for internal mounting.

Full range of shaft sizes from ⅛" to 3".

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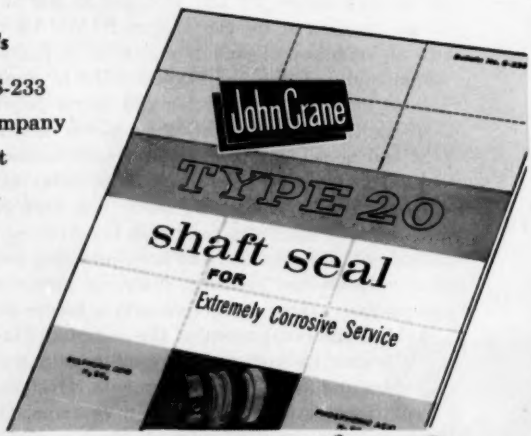
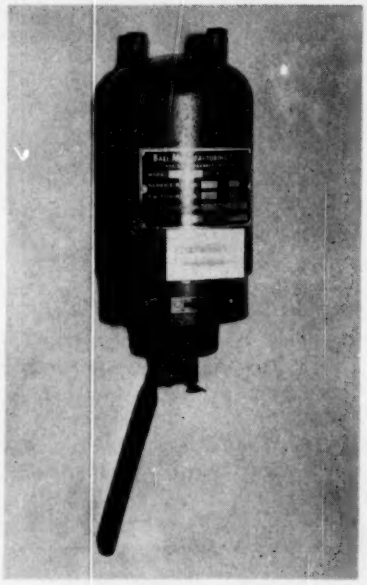


CRANE PACKING COMPANY

portion to changes in the measured temperature. It comes with various gas- or mercury-filled thermal systems.

Heart of the device is a temperature-compensated rebalancing diaphragm capsule that has a thermoelastic coefficient that minimizes zero and span shifts resulting from ambient temperature changes. For ease of cleaning and adjustment, the pilot valve is located in an enclosure at the bottom of the case.

For applications where extreme vibration is a problem, the gas-actuated thermal systems are particularly suitable. An air kit can be supplied for installations where the transmitter is located some distance from the input air supply, and higher-pressure instrument air must be pressure-corrected to the 20 psi. at which the unit works. **—Minneapolis-Honeywell Regulator Co., Philadelphia. 296A**



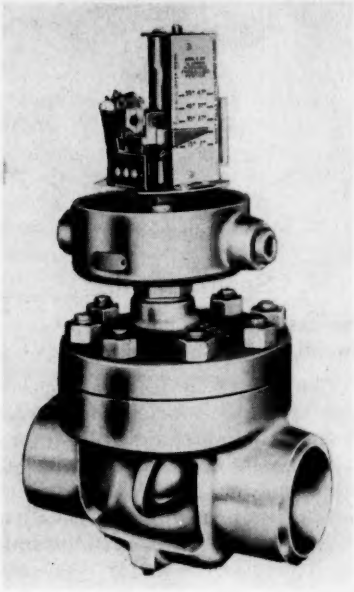
Flow switch

Suitable for any type of fluid, magnetic unit has no packing.

There is no packing or diaphragm to leak in this flow switch that can be preset to shut off a pump and/or sound an alarm if flow stops or increases excessively

due to a line break. The actuating vane is mechanically linked to a magnetic plunger, which in turn operates a microswitch external to the fluid flow.

A sealed stainless steel cylinder between the plunger and switch transmits the magnetic impulse so there is no possibility of a leak. Cost: less than $100.—**Ball Mfg. Co., Inc., Torrance, Calif.** 298A



Swing-check valve

Full-flow unit also controls flow by noting position of valve disk.

Operating with a magnetically coupled valve disk that indicates its position, a swing-check valve remotely signals flow or no-flow and/or provides an interlocking safety control based on conditions in the pipe.

The unit can also be calibrated for various fluids, with the position of the disk indicated on an external index. An electrical switching element can provide a signal when the valve disk reaches any preset position. From 10 to 50 deg. of adjustment can be made in the field without isolating the valve from the line.

Said to handle almost any liquid at a wide range of pressures and temperatures, the valve can be op-

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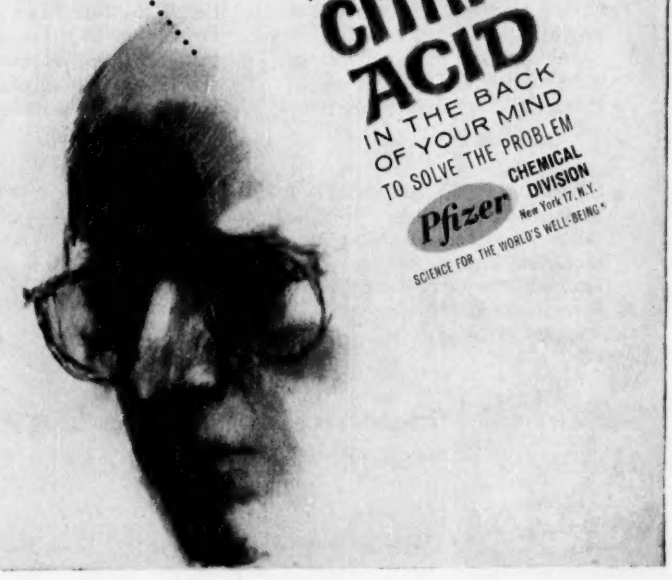

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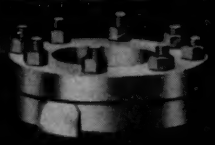

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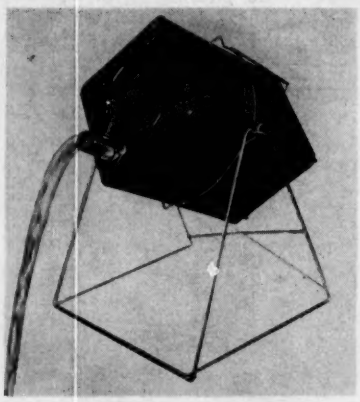
erated with either electrical switch or pneumatic pilot mechanisms.—**Magnetrol, Inc., Downers Grove, Ill.** 299A



Spout, cradle

Devices facilitate handling of liquids in 5-gal. containers.

Two handy devices can speed and ease the pouring of liquids from 5-gal. containers and larger.

An easily attachable spout of aluminum or plastic contains a built-in vent, making it possible to pour a carefully measured amount of liquid, or to empty the can quickly.

Held in place by spring tension, the spout fits any size opening from 1¾ to 3 in. Two other units within this range are equipped with a double cap. One side seals the container, the other contains an offset pouring spout.

A companion device is a heavy wire cradle that holds square or round 5-gal. can or bottle. Used on floor or bench, or mounted on the wall, it holds the containers firmly, tips easily for pouring.—**B&R Stearns Mfg. Co., Inc., Oakland, Calif.** 300A

Meter readout

Central reading panel indicates values from distant instrument.

Positive-displacement liquid meters can now be read by personnel

up to a half mile away, with a readout device that operates without an outside power source. Called Read-o-Matic, the instrument may be calibrated in gallons or cubic feet, or other units if desired.

The unit is powered by a self-contained generator inside the meter to which it is attached. Rotary motion of the generator's input shaft turns a magnet that rotates over six coils. Gears turn until the magnet reaches its maximum movement, then are released under tension of a torque spring.

Quick return of the magnet over the coils creates an electrical pulse for transmission to the remote reading panel. Each pulse represents the passage of a fixed volume of material. Distance is limited only to a 10-ohm total line resistance.—**Badger Meter Mfg. Co., Milwaukee.** 300B

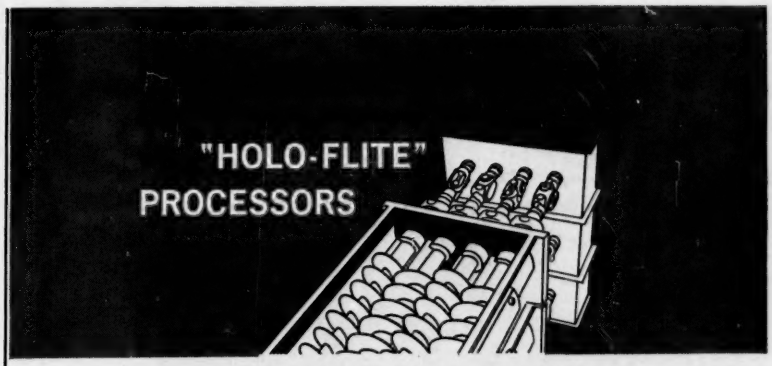
Briefs

Conospherical crystallizer has maximum cross-sectional area at its boiling surface to provide a large vapor-release area and reduce entrainment. Horton-type unit requires minimum wall thickness to withstand external and internal pressures.—**Chicago Bridge & Iron Co., Chicago.** 301A

Differential thermistor thermometer, capable of measuring temperatures to 0.001 C., reads directly, can be used as a single point or difference-between-two-points measuring device. Range is −60 to +300 C.—**Fiske Associates, Inc., Bethel, Conn.** 301B

Impingement-plate scrubber wet-cleans, absorbs or cools gases by turbulent interaction of gas and liquid on stainless steel baffle plate. Single-stage unit can handle dust loadings at the inlet up to 100 grains per cu. ft. Liquid consumption is said to be 1-3 gal./1,000 cu. ft.—**The W. W. Sly Mfg. Co., Cleveland.** 301C

Teflon-lined rubber tubing handles corrosive fluids at temperatures



The secret is **continuous** bulk flow operation — far faster and more efficient than batch processing. Heating or cooling fluid circulates through the hollow shaft and flights of a conveyor screw, thus processing granulars, fluids, or sludges as they flow along. Gentle conveying action minimizes particle degradation and dusting. Broad operating range. Heats to 500°F; cooling range, 1800°F to 0°F. Multiple "Holo-Flite" tiers can be stacked for high capacities in minimum floor space.

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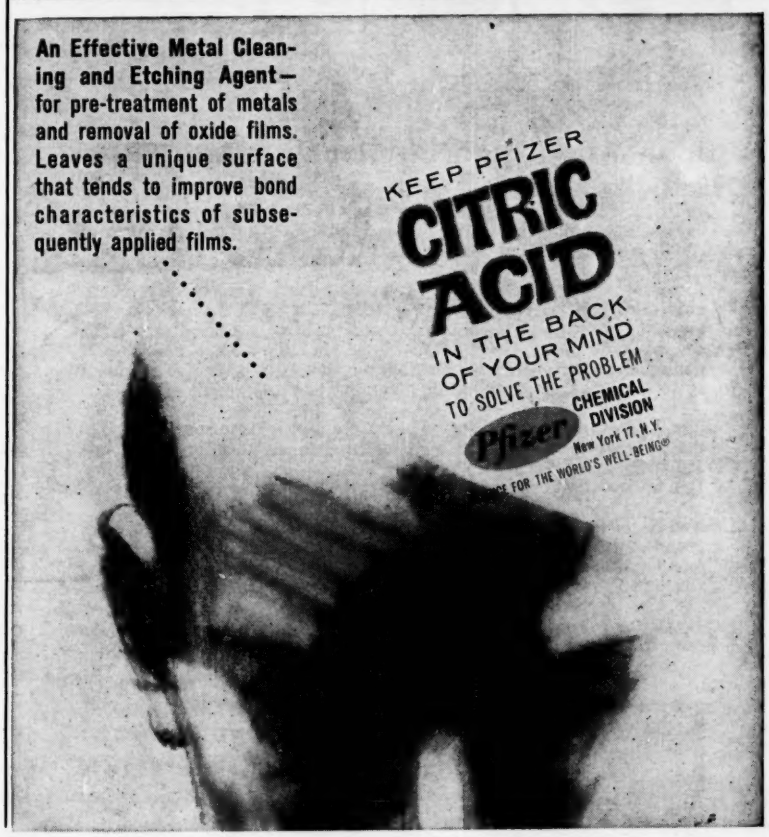
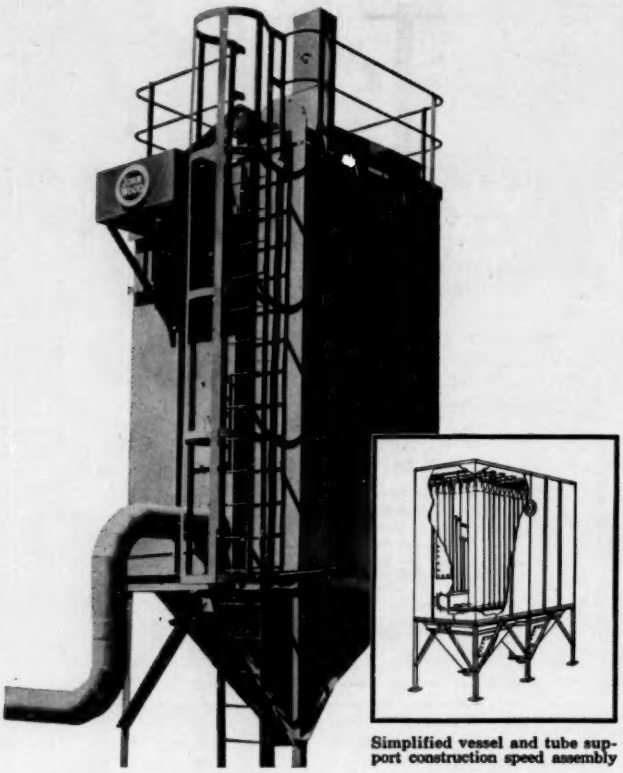


New Ideas On Dust And Fume Control



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New Engineering: John Wood Fabric Filters are but part of the complete line. Other equipment includes Interphase Reaction Scrubbers, Multi Cyclones, Involute Cyclones, Venturi Scrubbers and combination units. New designs are now under development.

New Service: John Wood Air Pollution Control is fully programmed from analysis of existing conditions to equipment installation. Frequently economies result that make the installation self-liquidating through lower maintenance and replacement costs.

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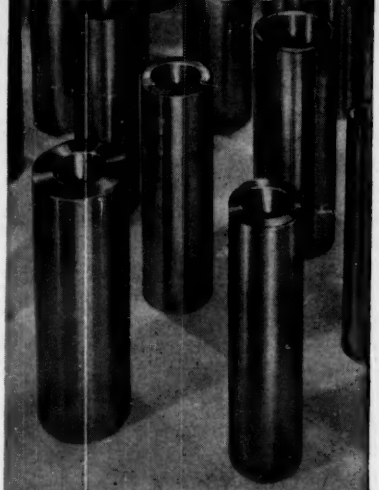

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	x 2¼		x 2½		x 4
3	x 2		x 2¾	4¾	x 2¼
	x 2¼		x 3		x 2½
	x 2½		x 3¼		x 2¾
3¼	x 2		x 3½		x 3
	x 2¼	4¼	x 2		x 3¼
	x 2½		x 2¼		x 3½
	x 2¾		x 2½		x 3¾
3½	x 2		x 2¾		x 4
	x 2¼		x 3		x 4¼
	x 2½		x 3¼	5	x 2½
	x 2¾		x 3½		x 2¾
	x 3		x 3¾		x 3
3¾	x 2	4½	x 2		x 3¼
	x 2¼		x 2¼		x 3½
	x 2½		x 2½		x 3¾
	x 2¾		x 2¾		x 4
	x 3		x 3		x 4¼
	x 3¼		x 3¼		x 4½

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as high as 300 F. Combination of Teflon and neoprene jacket makes tubing tough, flexible, and resistant to collapsing under severe conditions. Size range: ⅛ to ½-in. I.D., with working pressure to 125 psi.—**W. S. Shamban & Co., Culver City, Calif.** 301D

Rotameters used as purge meters are made of acrylic plastic, metals and glass. Designed for minimum space, units operate to 100 psi. with air capacity of 0.01 to 90 std. cu. ft./hr., water capacity 0.001 to 20 gph. O-ring seals eliminate body stress. — **C-Mar Sales Div., Chem Flow Corp., Little Falls, N. J.** 303A

Automatic pyrometer measures and controls extremely high temperatures continuously. Unit is said to be effective within one degree for temperatures to 4,000 C. With special attachments, it can operate in the range of 10,000 C.—**Atomics International, Div. of North American Aviation, Inc., Canoga Park, Calif.** 303B

Equipment Cost Indexes . . .

	Dec. 1960	Mar. 1961
Industry		
Avg. of all	237.3	237.2
Process Industries		
Cement mfg.	231.6	231.3
Chemical	238.1	238.0
Clay products	225.1	224.8
Glass mfg.	224.8	224.7
Paint mfg.	229.4	229.7
Paper mfg.	229.4	229.3
Petroleum ind.	234.3	234.7
Rubber ind.	237.1	237.6
Process ind. avg.	236.1	235.9
Related Industries		
Elec. Power equip.	238.3	237.9
Mining, milling	239.5	239.4
Refrigerating	268.0	268.5
Steam power	224.5	224.9

Compiled quarterly by Marshall and Stevens, Los Angeles, for 47 different industries. See Chem. Eng., No. 1947, pp. 124-6, for method of obtaining index numbers; Mar. 6, 1961, pp. 115-116, for annual averages since 1913.

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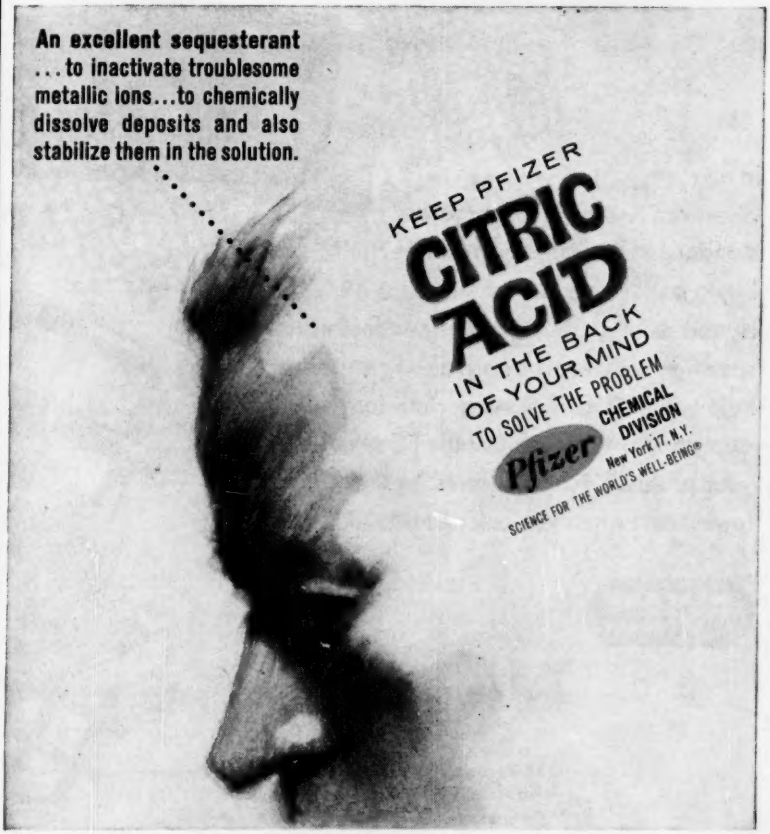
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APPLICATION: THE ESSENCE

SEPARATION PROCESSES IN PRACTICE. ED. BY ROBERT F. CHAPMAN. REINHOLD. 209 PAGES. $4.95.

Reviewed by James O. Osburn, Professor of Chemical Engineering, State University of Iowa.

In this era of increasing emphasis on theory, the engineer needs to be reminded occasionally that the essence of engineering is application. This is a book about practical applications, and as such would interest engineers who want to learn about practice in the areas represented.

Presented at a meeting of the Philadelphia-Wilmington Section of the AIChE, the several papers are written with authority and give the reader an introduction to the subject. Bibliographies at the end of each section provide keys to further study.

The first article, "Fundamentals of Mass Transfer Processes," by Leon Lapidus, is an exception, as it deals with theory rather than practice. It is a good introduction to some modern concepts in mass transfer.

Other sections deal with extraction (Braun, McCormick, and Fenske), ion exchange (Moison), crystallizers (Saeman), electric membrane processes (Katz), separation of aromatics and paraffins by solvent extraction (Scheibel), and fractionating column trays (Eagle).

The aim of the book is to "supply practical information for the young engineer." This is what it does.

USEFUL IMPETUS

GAS CHROMATOGRAPHY—1960. ED. BY R. P. W. SCOTT. BUTTERWORTHS. 466 PAGES. $17.60.

Reviewed by Horace P. Warrington, Jr., Sterling-Winthrop Research Institute.

Like its predecessors in 1956 and 1958, this book will become a basic reference for many years in a field where most works are outdated in two years. Each of the collection

of 29 papers, presented at the third symposium of the Gas Chromatography Discussion Group held at Edinburgh in June 1960, represents a very thorough study of its stated title and is followed by a discussion almost as useful as the paper itself.

The majority of the entries are concerned with solving problems in the analytical chemist's laboratory. For the engineer involved in the use of design of chemical processing equipment, there is the paper of G. Iveson and A. G. Hamlin entitled *A Gas Chromatographic Apparatus for In Line Analysis of Corrosive Inorganic Gases.*

Although progress has been slow in the use of gas chromatography as a tool for separating large quantities of materials, useful impetus is given to this field by the paper of F. H. Huyten, et al., entitled *Improvements in the Efficiency of Large Diameter Gas Liquid Chromatography Columns.*

WANTED: A HANDBOOK

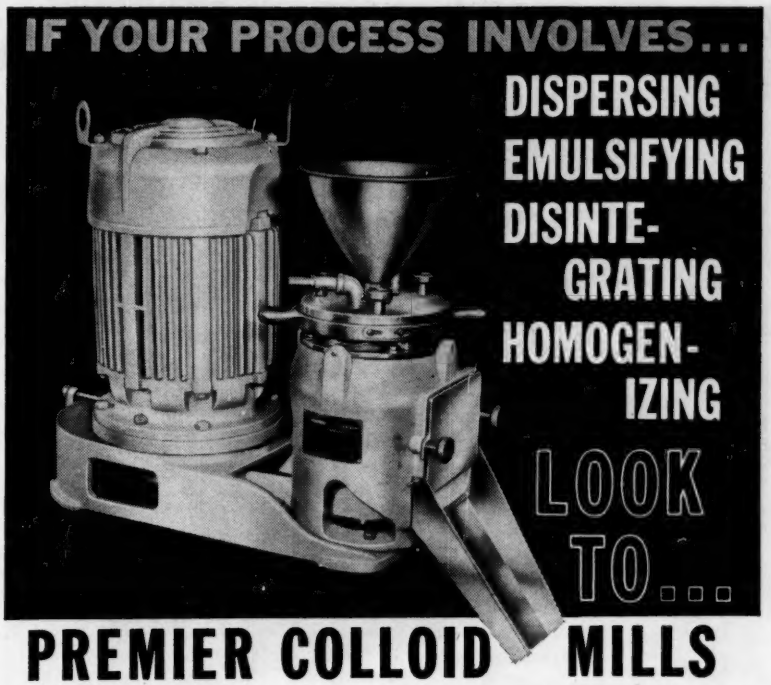
PLASTICIZERS. 2ND ED. BY D. N. BUTTREY. FRANKLIN PUBLISHING CO., INC., PALISADE, N. J. 213 PAGES. $7.50.

Reviewed by Irving Skeist, Skeist Laboratories, Inc., Newark, N. J.

The present volume appears to be extracted largely from the British trade literature. It consists of 12 chapters on the various groups of plasticizers, "Hydrocarbon and Aromatic Extenders" receiving equal space with "Phthalate Esters."

A proprietary petroleum derivative gets four pages, while butyl acetyl ricinoleate, tributyl citrate and di-2 ethylhexyl phthalate are each accorded slightly over two pages. Di-isooctyl phthalate rates somewhat less than half a page; possibly this is a reflection of the greater availability in England of heptyl and nonyl alcohol esters.

The epoxy plasticizer-stabilizers are not even mentioned. Can it be that this American invention, a decade old, has not yet crossed the Atlantic? The reader will seek in vain for advice on the formulation



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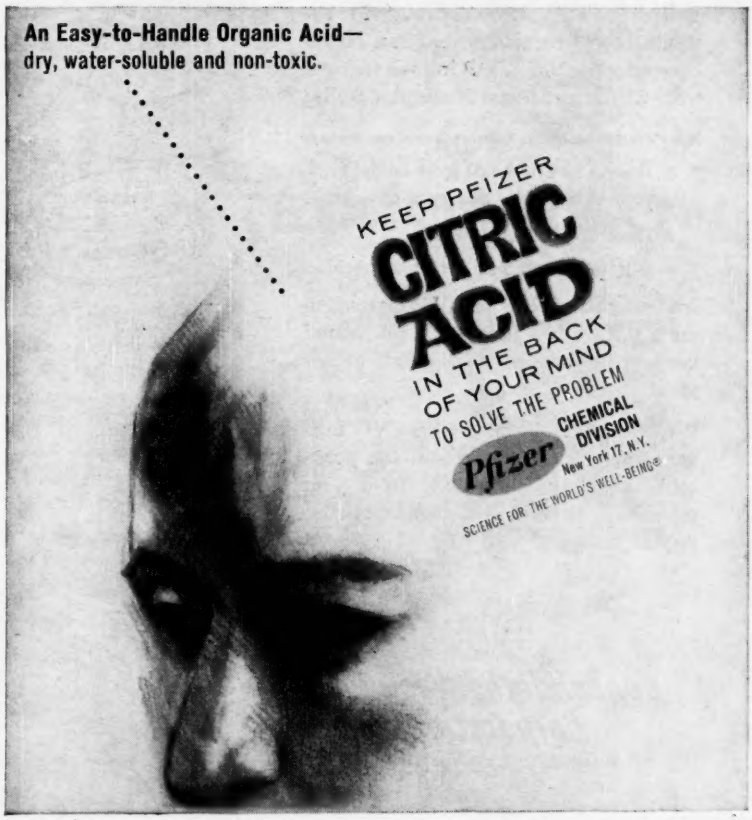

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A handbook of plasticizers is needed. It would offer the user of plasticizers a guide to their characteristics, aiding him in his formulation problems. A critical selection would be made from the abundant technical literature, and manufacturers' brochures would be quoted circumspectly.

The space devoted to the various plasticizers would be related to their significance in current technology, reflecting the facts that the great bulk of plasticizer usage is in vinyl chloride compositions and that the phthalates are employed in greater volume than all other plasticizers together, with the octyl phthalates far in the lead.

Compatibility would be discussed in terms of the solubility parameters (cohesive energy densities) of plasticizers and polymers. Modulus, power requirements, hardness, low temperature flexibility, volatility, stability, flame retardance, migration, and especially cost, would be among the topics treated. Pertinent ASTM tests or their British counterparts would be described briefly. Typical formulations for the more important vinyl, cellulosic and other end-products would be presented.

PATENTS

AN OUTLINE OF UNITED STATES PATENT LAW. BY RICHARD E. BRINK, DONALD C. GIPPLE AND HAROLD HUGHESDON. INTERSCIENCE PUBLISHERS, NEW YORK. 280 PAGES. $7.50.

Reviewed by William C. Long, Chief Patent Attorney, Scientific Design Co., New York.

As emphasized in the title, this book is in outline form. Its important points are keyed to the appropriate sections of the U. S. Code, Rules of Practice, or Manual of Patent Examining Procedure. It is designed to acquaint the reader with patenting, and protecting the rights to a patented invention.

The outline form used by the authors permits accomplishing their objective of covering a large

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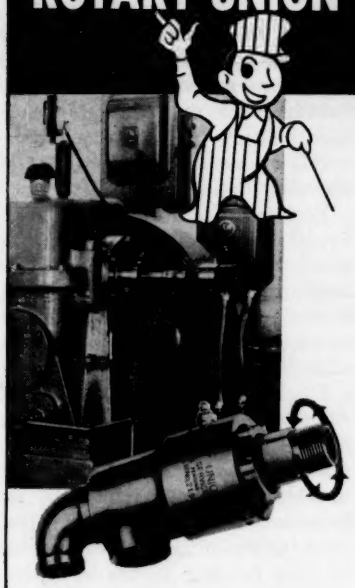

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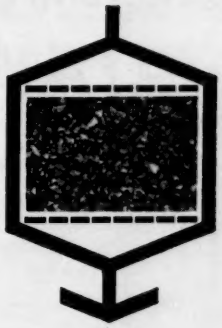

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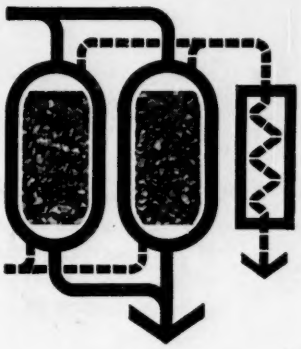

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Write for Literature Group J-46.

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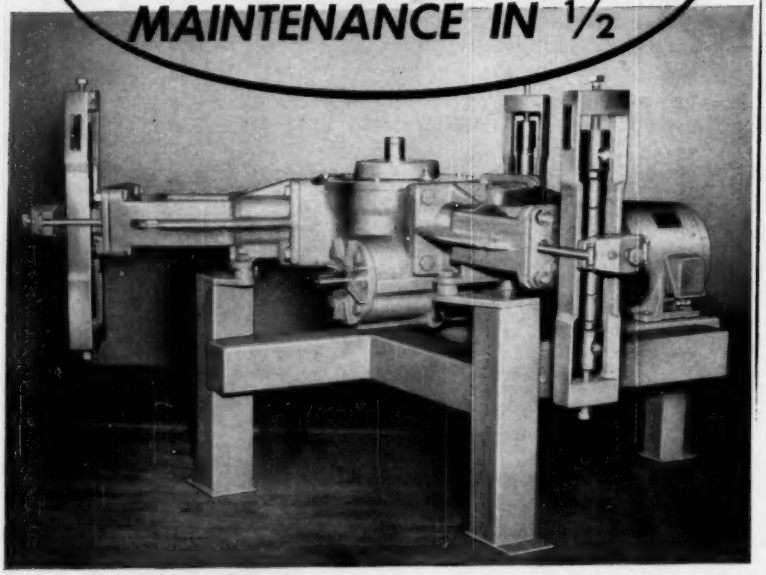
NEW METERING PUMP DESIGN CUTS MAINTENANCE IN 1/2



Wallace & Tiernan's new Heavy Duty Metering Pump is designed to take all pumping stresses in the gear case, not in the base. This pump stays in perfect alignment, holds accuracy for life. The tendency to twist components loose from the base is gone — and with it half the maintenance headaches.

Maintenance "musts" that remain are simplified by design. The entire stuffing box is removable to speed plunger repacking. Suction and discharge valves are dismantled for cleaning without disconnecting piping. The entire liquid end is changed by removing just four bolts and a clamp.

Because its design eliminates cantilever loads, the W&T Metering Pump does not require a massive base. A tubular steel base supports the pump, raises it to leave room for cleaning and piping underneath.

The unique drive unit is completely enclosed. Corrosion and foreign matter are sealed out . . . preventive maintenance built in.

All W&T Metering Pumps, Series 200, 400, and 600, have the same maintenance-free design. Capacities range from 0.065 gph vs 4000 psi to 4050 gph vs 170 psi.

For other helpful features, write Dept. L-7.29.

WALLACE & TIERNAN INC.
25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

amount of material in a relatively short space. However, because of its use, the person who is not initially familiar with the patent law may have difficulty digesting and thoroughly understanding the wealth of material covered.

Pertinent statutes and Rules of Practice of the U. S. Patent Office are reprinted in appendixes that comprise about half of the book. A bibliography briefly dealing with foreign patent practice is also included.

Engineers will find the book of value in obtaining an over-all grasp of the requirements of a patentable invention, procedural aspects of obtaining patents and the enforcement of patent rights. However, much of the material—such as that relating to the mechanics of patent work—will not have particular relevance.

And Also Received

Bibliographic Survey of Corrosion 1956. (Copyright 1960.) 240 pages. Seventh in a series of collected abstracts from the 1945-56 literature on corrosion, this issue is a compilation of abstracts from articles published in 1956. General arrangement of the book is confusing, as articles on the same subject are not always grouped together, but two indexes (author and subject) make for quick location of a specific abstract. $22.50 to NACE members, $27.50 to nonmembers. Write: National Assn. of Corrosion Engineers, T. J. Hull, Exec. Secy., 1061 M & M Bldg., Houston 2, Tex.

Science Information Personnel. By L. Cohan and K. Craven. A little (74 pages) paperback booklet that "describes specifically the increasing need for modern foreign language instruction in the education of science information personnel." Authors discuss present undergraduate and graduate education courses and standards in language, lack of communication between industry recruiters and educators, other important areas; and make several proposals (one of which is the founding of a "graduate school of science information and a one-year graduate curriculum leading

to an M.S. in information"). Work is the product of research sponsored by the Modern Language Assn. under a contract from the Dept. of Health, Education and Welfare. $1.50. Write: Science Information, P. O. Box 624, Radio City Station, New York 19.

Flow Meter Engineering Handbook. 3rd ed. C. F. Cusick, ed. In 170 pages, this well-produced reference work presents—and briefly comments on—definitions, equations, tables (57 of them), diagrams, and descriptions of both the theory and the hardware of fluid-flow mechanics. $7.50. Write: G. A. Stauter, Minneapolis-Honeywell Regulator Co., Wayne & Windrin Aves., Philadelphia 44, Pa.

More New Books

Engineering Management. 2nd ed. By S. A. Robertson. Philosophical Library. 467 pages. $10.

Name Index of Organic Reactions. By J. E. Gowan and T. S. Wheeler. Interscience. 293 pages. $8.50.

Review of Textile Progress. Vol. 11—1959. Ed. by M. Tordoff. Textile Book Publishers Inc. (Interscience). 448 pages. $10.

Silicones. Ed. by S. Fordham. Philosophical Library. 252 pages. $10.

The Electron Microscope. By M. E. Haine and V. E. Cosslett. Interscience. 282 pages. $9.25.

A Hole in the Bottom of the Sea. By W. Bascom. Doubleday. 352 pages. $4.95.

Assault on the Unknown. By W. Sullivan. McGraw-Hill. 460 pages. $7.95.

Plastics Tooling. 2nd ed. By M. W. Riley. Reinhold. 216 pages. $7.50.

Cost Reduction Guide for Manufacturing Management. By H. C. Morse and E. E. Wyatt. Distributor: Hitchcock Publishing Co., Wheaton, Ill. 244 pages. $18.

Industrial Building. Vol. 1. By various authors. Clapp & Poliak, Inc., 341 Madison Ave., New York, N. Y. 232 pages. $10.

Extractive Metallurgy of Copper, Nickel, and Cobalt. Ed. by P. Queneau. Interscience. 647 pages. $22.50.

Treatise on Analytical Chemistry. Vol. 1, part 2. Ed. by I. M. Kolthoff and P. J. Elving. Interscience. 471 pages. $16 (by subscription: $14).

THE Anatomy OF A ROTAMETER

This is a rotameter skeleton. But it's an exo-skeleton like nature gave the lobster. And like the lobster's, it must be strong and rigid — powerful protection for what's inside.
That's why the frame of Wallace & Tiernan's new Varea-meter is one rigid piece. No bolts or pins hold parts together. Stainless steel shrugs off corrosion. Deep-formed construction resists pipe strain, protects tube alignment. You have less maintenance; life-long, positive metering accuracy.
Other Varea-meter extras: Fewer parts overall, end fittings that rotate through 360°, and a tube-locking clamp that's easily controlled yet so powerful it ends the unseating of tubes.
Varea-meters come in ⅜" through 3" sizes with 5" and 10" scales. They meter up to 310 gpm water or 1300 scfm air over a range of at least 10 to 1.
For more information, Write Dept. V-7.29

WALLACE & TIERNAN INC.
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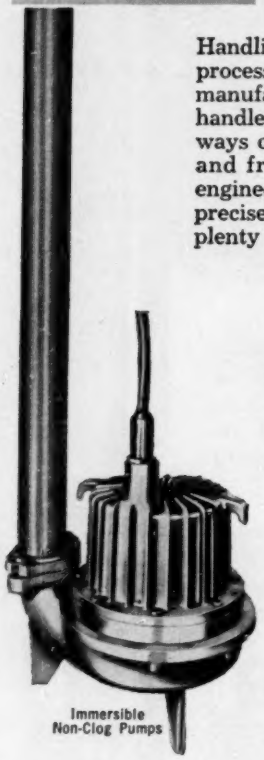
here's why **most plant engineers prefer WEINMAN PUMPS**



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Handling of liquids . . . for heating, cooling and processing . . . is an important facet of modern manufacturing. The tremendous volume of fluids handled prompts today's industrial engineer to find ways of insuring a steady flow of vital liquids to and from the job. That's why more and more engineers are turning to Weinman to meet their precise pumping requirements. And, they find plenty of reasons to back their buying decision:

1 **WEINMAN EXPERIENCE.** More than 50 years of pioneering developments that are today's standards assures you of the right pump for each job.

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3 **QUALIFIED RECOMMENDATIONS.** Made after a careful analysis of your present and future pumping needs. You get the pump that fits your job today *and* tomorrow.

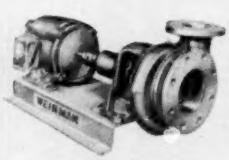
4 **SIMPLE DESIGN AND RUGGED CONSTRUCTION.** Weinman Pumps are built for easy maintenance and long, trouble-free service.

5 **INSTALLATION AND SERVICE.** You get skilled assistance before, during and after installation to insure proper operation twenty-four hours a day.

When you're faced with a pumping problem . . . get the right answer from your Weinman specialist . . . you'll find his name in the Yellow Pages. Or, write to us.

General Service Unipumps

Split Case, Multi-Stage Pumps



Single Stage, End Suction Pumps

MEMBER

THE WEINMAN PUMP MFG. CO.
290 SPRUCE STREET COLUMBUS 15, OHIO
CENTRIFUGAL SPECIALISTS

PRO & CON . . .

(*Continued from page* 7)

ployed, few schools offer any graduate studies in chemical engineering, let alone evening courses. A good example is the Washington, D. C., area.

Probably this situation is created and perpetuated by lack of demand for such courses. The few chemical engineers who do wish to pursue graduate studies are forced to take what is available—usually chemistry, physics or mathematics. At least this has been my experience from living in three densely populated areas of the country.

MARVIN FLEISCHMAN
Rockville, Md.

Pro: Steam-Heated Platens

Sir:

One point overlooked in the Cost File on hydraulic presses (Apr. 17, p. 194) is that the data refer to hydraulic presses with steam-heated platens. Non-heated platen presses would cost less and are not as widely used.

R. O. BATHIANY
Weyerhaeuser Co.
Longview, Wash.

That's Right, You're Wrong

Sir:

Your Feb. 20 Plant Notebook (p. 172) carried a short article by G. J. Caras, "Simple Method Proves Multiplication." It is quite misleading. The procedure suggested is not capable of proving the multiplication correct; it is capable merely of proving that the multiplication is *not* correct.

This distinction may be easily illustrated by analogy to the blood tests often used in paternity suits. A negative test may prove that one is not the father. On the other hand, a positive test does not prove that one is the father, but only that one is a member of the class of persons capable of being the father.

Of academic interest is the question: Why is Mr. Caras' method capable of proving that a tentative answer is not correct? The answer

to this question I must leave to your more knowledgeable readers.

R. B. FLOYD

San Gabriel, Calif.

► *Maybe our headline should have read, "Simple Method Disproves Multiplication."*—ED.

Design vs. Construction

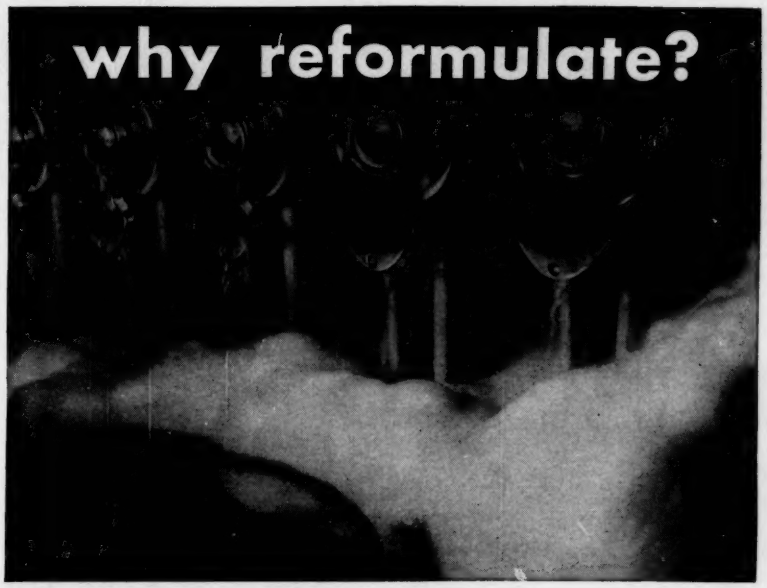
Sir:

In spite of the trimmings (slide rule, key, etc.) your status symbol of the engineer (Apr. 3, pp. 161-2) indicates a construction worker.

Why not a true symbol of an engineer while truly at his work—designing. That is creating. It would look like this: a man in a white shirt with his sleeves rolled up, tie pulled down and his shirt collar open, bending over a drafting board.

Yes, I know the popular conception: "That's a draftsman." If so, why is it that so many of these "draftsmen" have enough in the way of diplomas and certificates from universities, engineering societies and state registration boards to cover quite a few square feet of wall space?

If this symbol was widely circulated maybe sales engineers who call on us wouldn't tell us later on the phone that the person they talked to was "only a draftsman." Nor would your sophisticated journal banner-line its front cover with "PREDICT DRAFTING COSTS" to announce an article (May 30,



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Because so little is required, General Electric Anti-Foam 60 kills foam *without* affecting the other properties of your process. Thus you avoid the cost of reformulating or redesigning your entire system to end costly foaming.

G-E Anti-Foam 60 disperses instantly in aqueous systems, making it easier to use and faster-acting than other anti-foams. It also comes to you in a higher concentration (30% silicones) for greater convenience in storage and handling.

Many manufacturers have found that G-E Anti-Foam 60 pays for itself by reducing processing time, eliminating costly boil-overs, increasing capacity and improving the quality of their finished product. General Electric Anti-Foams are available for both aqueous and non-aqueous systems.

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Application

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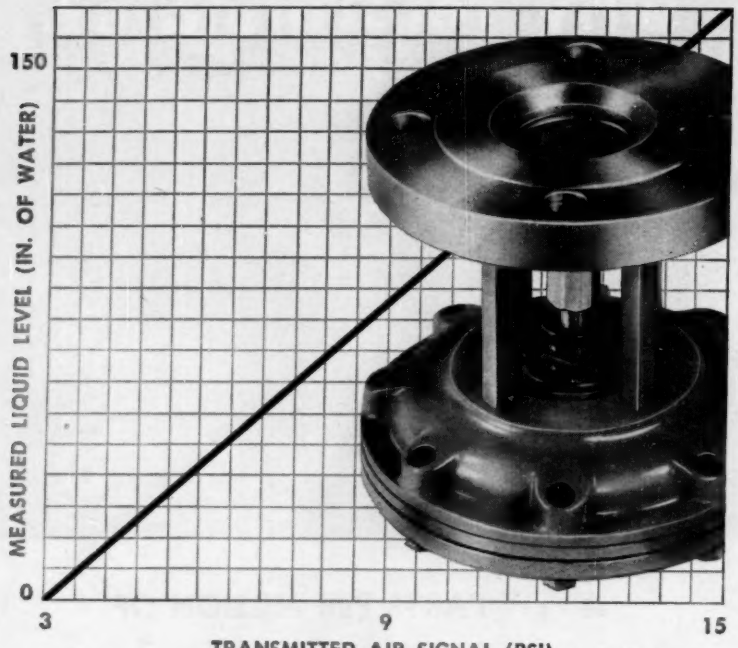
City_____ Zone_____ State_____

TYPICAL PERFORMANCE CURVE OF MODEL "P" TRANSMITTER



LOW COST PRESSURE AND LIQUID LEVEL TRANSMITTER WITH QUALITY FEATURES FOR DEPENDABLE OPERATION

The Conoflow Model "P" Transmitter is a low cost, rugged instrument which measures pressure and liquid level and transmits a *linear* 3-15 psi signal to standard receiver elements. Incorporates many features not found in more expensive devices for guaranteed dependable operation.

Safety—Process liquids and gases cannot back up into air lines and damage costly instruments. This is assured by the complete separation of measuring diaphragm from pneumatic pilot.

Simple Installation—The Model "P" can be mounted either horizontally or vertically on open or closed vessels. No dip tubes, floats or other mechanical devices are required inside the tank.

Long Life—Only the corrosion-resistant *Inconel X* diaphragm is exposed to the measured material. Preformed diaphragm will not work-harden or fatigue; withstands pressures to 500 psi and temperatures to 450°.

Versatile—Can be used for practically any service; ideal for viscous fluids or materials with solids in suspension; also for flowing bulk materials such as pigments, flakes, etc.

Choice of Ranges—Available for measuring ranges as low as 0 to 100" of water and pressures as high as 250 psi. Ranges can be changed in the field.

Specifications—New Bulletin P-36-1 contains complete specifications on the Conoflow Model "P" Transmitter. Write for your copy today or ask for a quote. No obligation. Conoflow Corporation, 2100 Arch Street, Philadelphia 3, Pa.

CC-1003

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FOREMOST IN FINAL CONTROL ELEMENTS
SUBSIDIARY WALWORTH

1960, p. 114) that assumes all engineering beyond process engineering to be "drafting."

PHILIP J. BAUKOL
Professional Engineer
Vancouver, B. C.

Distillation Error Rectified

Sir:

A current project required calculation of a batch distillation column, so I referred to my recent article in *Chemical Engineering* (Feb. 6, pp. 87-98). To my surprise and chagrin, I found that the denominator in Eqs. (16) and (17) omitted the term $(1 - L/V)$. In both cases, the quantity following the integral sign should read $dx/(1 - L/V)(x_D - x_w)^3$. In the example which followed these equations, the tabulated numbers and the graphical integration were correct.

B. BLOCK
Abbott Laboratories
North Chicago, Ill.

Con: Blind Job Ads

Sir:

I recently read P. J. Brennan's interesting article, "What It Takes To Get That New Job," in your Feb. 20 issue (pp. 158-62).

Mr. Brennan says that one should not waste his time answering blind ads in the newspapers. I am at a loss to know why he makes such a recommendation.

H. I. PRICE
Foundation of Canada
Engineering Corp. Ltd.
Montreal, Canada

Sir:

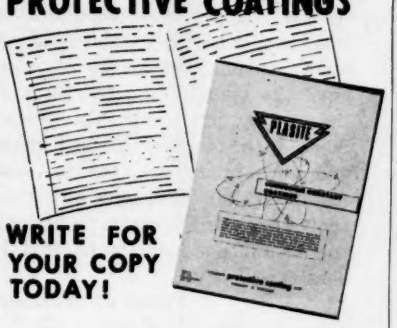
In your editing of my manuscript you unconscionably deleted my qualifying statements. As originally written, this sentence said:

"But do not waste your time with blind ads in the newspapers unless the ad describes you practically down to the color of your eyes. And then it may be your company seeking your replacement."

I think Mr. Price will agree that this puts a somewhat different light on the matter.

Simplify

YOUR SELECTION OF PROTECTIVE COATINGS



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Jet-swirl action. Gas, drawn upward through perforated plate, is divided into thousands of jets. Each strikes the wetted impingement surface directly above, bounding and rebounding against various grid surfaces. The turbulent intermixture of gas pressure and liquid causes complete saturation.

NEW FROM SINCE 1874 SLY

IMPINJET™ SCRUBBER

High Efficiency... Low Operating Costs

Now Sly brings you the simplest, most effective wet cleaning method known. The new IMPINJET Gas Scrubber assures thorough saturation of particles, even in sub-micron sizes.

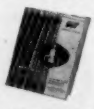
There are no moving parts. Complete cleaning results from the turbulent interaction of gas and liquid, as effected by the impingement baffle plate.

Pressure drop and resulting power requirements are low. Liquid consumption is only 1 to 3 gallons per 1000 CFM at 20-40 psig.

The IMPINJET Scrubber utilizes the proven principles contained in the original Harmon patents basic in the development of the impingement plate scrubber. Single-plate units effectively clean gases resulting from a wide variety of industrial processes. Multi-plate units are available for absorption, cooling and extra-high-efficiency applications.

For dust suppression, *wet or dry,* consult Sly — maker of the Dynaclone, the self-cleaning, continuously operating dry dust filter.

Send For New IMPINJET Catalog



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PRO & CON . . .

My judgment is based partly on personal experience and partly on conversations with friends who have had the same experience. Blind ads in newspapers are often "plants" by personnel departments who are not really interested in hiring anyone, but merely wish to gage the state of the market and the going price for manpower. Some such ads may be legitimate and undoubtedly are, but in most instances one will receive either no reply at all, or the company placing the ad will not identify itself if it does reply.

PETER J. BRENNAN
General Dynamics Corp.
La Jolla, Calif.

Two Helium Chambers

Sir:

Your panel discussion on the cryogenics industry (Feb. 20, pp. 94-100) contained a misstatement. Mr. Murray of Linde stated that his company was building the helium refrigerator for the 7x12-ft. space simulator for the Air Force.

CryoVac is building this unit under a subcontract with the Stevens Co. of Newport, Ky., which is installing the vacuum chamber. The refrigerator was designed for CryoVac by James G. Pierce & Associates of Columbus, Ohio. When this project is completed this spring, it will be the first large high-performance chamber using cryogenic pumping to go into operation in this country.

CHARLES B. HOOD
CryoVac, Inc.
Columbus, Ohio

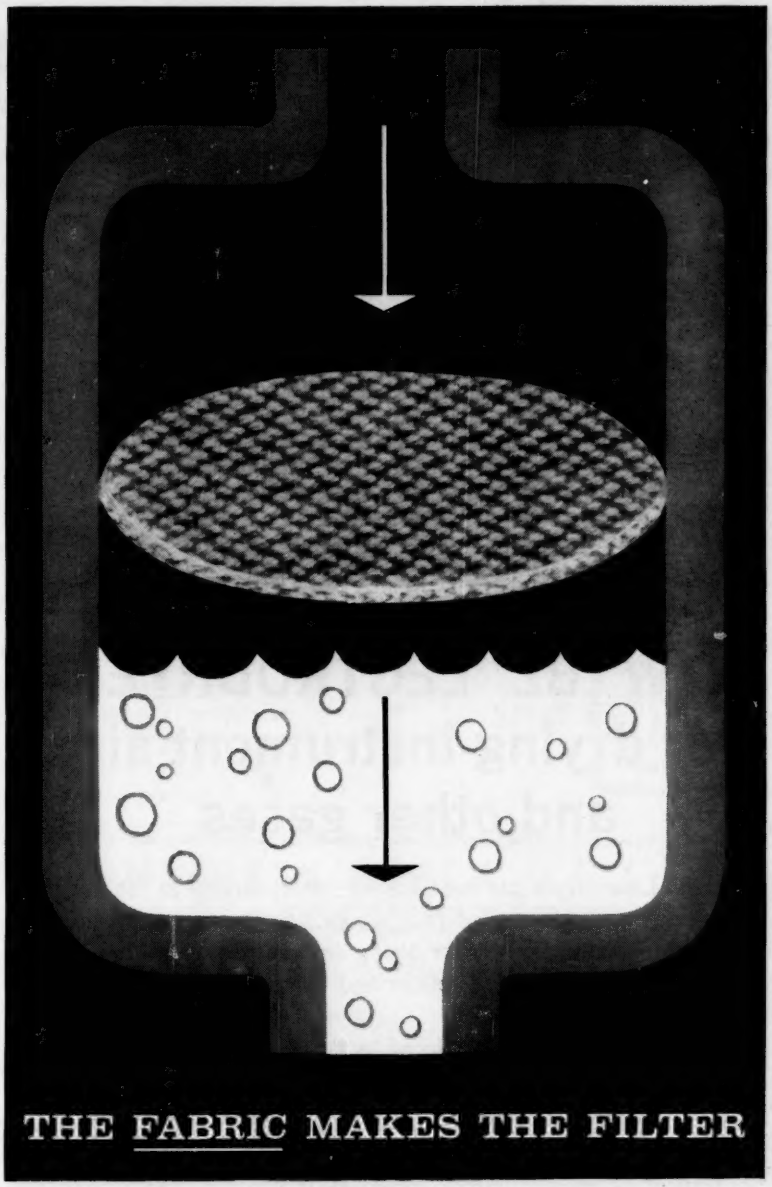
► *Both Mr. Hood and Mr. Murray are correct. It seems that there are actually two space simulators being built at Tullahoma—one by Linde, the other by CryoVac.*—ED.

Your comments and opinions are important. Send them to Editor, Chemical Engineering, 330 West 42nd St., New York 36, N. Y. They'll be welcomed.

technological breakthrough for measuring H_2O in H_2

The Beckman Hygrometer, equipped with the new hydrogen electrolytic cell, establishes new standards of accuracy for measurement of moisture in hydrogen streams. In the past, measurement of moisture in hydrogen has been marginal at best because of frequent catalytic reforming of H_2O within the cell, and subsequent remeasurement. ⌘ The new Beckman Hydrogen cell utilizes an element length where errors in efficiency and recombination are approximately equal and opposite, and hence cancel. Thus, you obtain readings of an accuracy heretofore unattainable. ⌘ If your problem is keeping hydrogen "dry" in process streams... in refining, catalytic reforming, and annealing, for example ...your nearest Beckman Sales Engineer can help you. Or write for application Data File 14-24-14.

Beckman
Scientific and Process Instruments Division
Beckman Instruments, Inc.
Fullerton, California



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And that's why so much time and effort go into the manufacture of U.S. Royal Filter Fabrics—why the depth and breadth of U.S. Royal textile experience is so important to you. "U.S." fabrics combine efficient filtration with maximum resistance to heat, chemicals and abrasion. Cake retention-and-discharge properties are excellent. Special weaves and blends of natural and synthetic fibers meet the most specialized filter needs. Through independent research, painstaking development and carefully controlled production, our textile engineers continually seek new ways to make fibers and fabrics serve you better. To find the filter fabric that can serve your operations best, contact our Industrial Textiles Department at the following sales offices:

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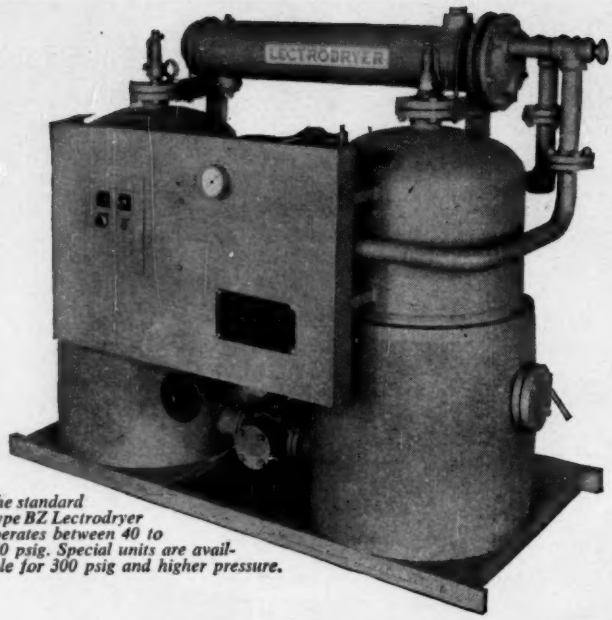
102 N. Brand Blvd.	P.O. Box 461	1230 Ave. of the Americas
CHapman 5-5961	SKyline 4-3116	CIrcle 7-5000

Textile Division
United States Rubber



The standard Type BZ Lectrodryer operates between 40 to 150 psig. Special units are available for 300 psig and higher pressure.

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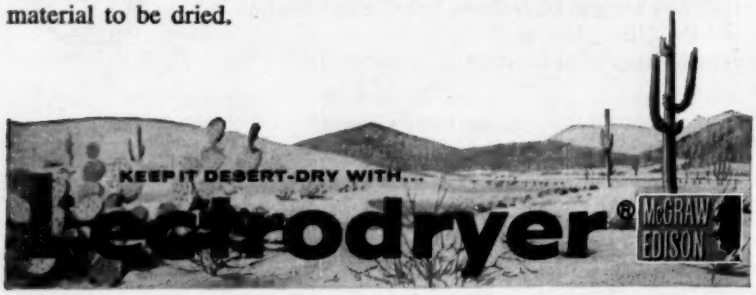
For years, Lectrodryer has been known for leadership in the design and production of adsorbent dryers...with a reputation for providing extra peak load capacity, greater drying dependability. Now here's an even *better* dryer for compressed air and other gases—the new Type BZ Lectrodryer.

Special emphasis has been placed in the Type BZ Lectrodryer on sound but *simplified* mechanical design. It is fully automatic, supplying continuous drying with no attention other than occasional lubrication. Since the valves and valve mechanism move only a few times per day, there is virtually no wear—unlike units which cycle frequently.

Bulletin BZ-161 describes this new Lectrodryer in detail. For a copy, or for drying help, write Pittsburgh Lectrodryer Division, McGraw-Edison Company, 303 32nd Street, Pittsburgh 30, Pa.

CASE HISTORY SHEETS—describing typical moisture-control installations—are available to help you plan your own drying systems for instrument air and other gases. Write for free copies—stating the material to be dried.



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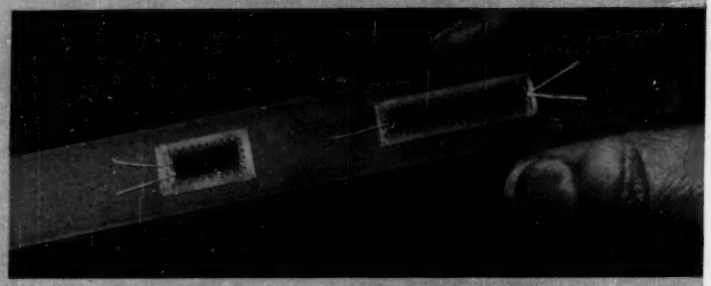

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Instruments & Controls

Actuator.....Type 470 delivers same power in either direction at any point of the stroke. Available in six basic sizes & for travel up to 4". Bulletin E-470.
124-125 *Fisher Governor Co.

Air Pollution Acralyzers.....Bulletin describes an automatic chemical reagent addition analyzer designed to monitor and record contaminant concentration in the atmocphere.
320A Beckman Instruments Div.

Alarm Indicating Monitor..... offers centralized monitoring of all important variables. The AIM is fast, reliable and compact. Further information is available.
297 *Hagan Chemicals & Controls

Chromatograph, Gas.....features tape-programmed control unit. The new tell-all bulletin on this new chromatograph is now available on request.
253 *Mine Safety Appliances Co.

Computer Systems.....ISI 609 information and computer systems give practical information for profitable control. Case history data are available.
275 *Information Systems, Inc.

Control Instruments.....Pneumatic Consotrol instruments consistently deliver on all counts. The whole story on these instruments in Bulletins 13-18 & 13-19.
26-27 *Foxboro Company

Control Loops.....Autronic control loops to assure on-stream success. A complete selection of equipment is available. Details are contained in Bulletin A-913.
185 *Swartwout Div., Crane Co.

Data Recorder.....Portable dynamic process data recorders feature self-contained input circuits compatible with all normal process transducers & analyzers.
R286 *Dresser Electronics

* From advertisement, this issue

Gauges.....Dial-type gauges show tank contents at-a-glance. Available to measure and indicate virtually any liquid at tank site or remotely. Literature.
351 *The Liquidometer Corp.

Hygrometer.....with the new hydrogen electrolytic cell for accurate measurement of moisture in hydrogen streams. Further helpful information in Data File 14-24-14.
L315 *Beckman Instruments, Inc.

Liquid Level Control.....New Sonac Ultrasonic Sensor system is unaffected by foam, liquid viscosity, specific gravity & vibration. Complete information.
97 *Aro Equipment Corp.

Magnetic Gages.....are available in four models to fit a variety of installation needs. Full details about these accurate and safe gages in catalog.
257 *Jerguson Gage & Valve Co.

Meters.....A 28-page technical bulletin, Meter Bulletin 566N lists liquids, helps pick proper sizes and features meters 2 to 2000 gpm. Available on request.
133 *Neptune Meter Company

Pneumatic Receiver.....Metagraphic receiver is the easiest yet to install, operate and service. The complete story on the new Metagraphic receiver is offered.
40-41 *The Bristol Company

Pneumatic Transmitter..... The 273 offers the widest differential pressure ranges, the highest safe working pressures & widest variety of housing materials. Data.
291 *Barton Instrument Corp.

Process Stream Analyzers.....help to reduce costs and improve products. Full details on the latest components for automation are available on request.
91 *Hallikainen Instruments

Recording Meter.....A pH meter and strip chart recorder in one. Continuously indicating. Further details are contained in Bulletin 3R which is available.
TL339 *Aanalytical Measurements, Inc.

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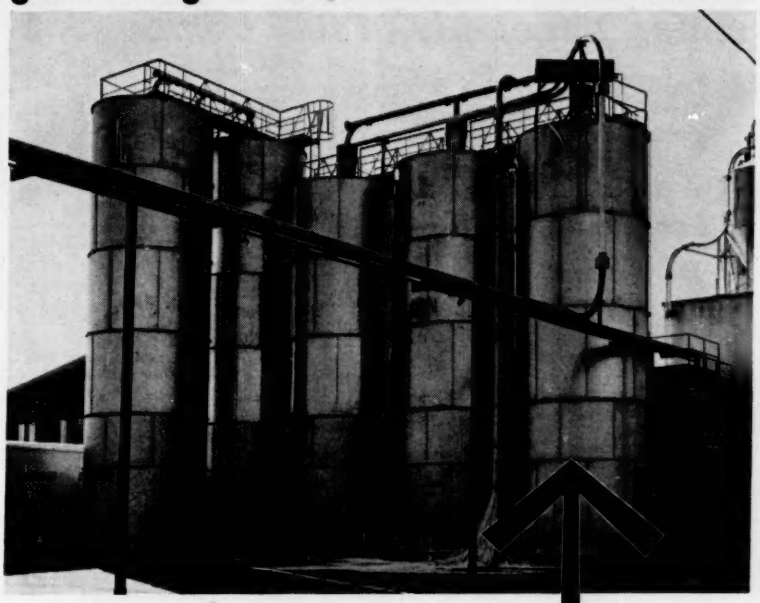

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L341 *Stratos, Div. of Fairchild Eng.

Relay Monitors.....Packaged pneumatic relay monitors control signals. Mite 70 can be integrally mounted on control valves or used elsewhere. Bulletin M-70.
BL357 *G. W. Dahl Co. Inc.

Rotameter.....The frame of the new Varea-meter is in one rigid piece. Varea-meters come in ¾" through 3" sizes with 5" and 10" scales. Information is offered.
309 *Wallace & Tiernan, Inc.

Strain Gages..... New weldable, prestabilized gages that install in minutes are now available. Two types are available, with a wide range of applications.
320 *Baldwin-Lima-Hamilton

Temperature Transmitter.....offers thermal system options with ranges from 125 deg. to 1,000 deg. F. Details on this new transmitter in S630-1 on request.
56 *Minneapolis-Honeywell

Thermometers.....feature a special dampening bearing and silicone for extra resistance to shock and vibration. Information on indicating & control instruments.
113 *American Standard Controls Div.

Thermometers.....Model Y dial indicating thermometers are available in four temperature ranges. Further information on these and the complete line of instruments.
6 *Electric Autolite Co.

Thermometers and Gauges.....Bimetal dial thermometers and high pressure gauges designed for use in diverse processing operations are described in a 4-page folder.
322A American-Standard

Transmitter..... Model "P" Transmitter measures pressure & liquid level & transmits a linear 3-15 psi signal to standard receiver elements. Specifications in Bul. P-36-1.
312 *Conoflow Corp.

Transmitter.....Acragage electric transmitters signal pressure changes to your central control panel for immediate reading. New folder LC-763 is offered.
282 *Robertshaw Fulton Controls

Transmitter.....The only DP transmitter that can be calibrated for output linear with flow as well as differential pressure without changing parts. Bulletin 98413.
18-19 *Taylor Instrument Companies

Ultrasonic Test Unit..... The fully transistorized Sonizon SO-300 may be used on practically any solid from .025 to 2.50" thick. Further information or demonstration.
T303 *Magnaflux Corp.

Chemicals

Activated Carbon.....purifies liquids & gases, recovers solvents and catalyzes. Literature Group J-46 is available on request for further information.
R307 *Barnebey-Cheney

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164 *Reynolds Metals Co.

Aluminum Silicate Pigments.....are mineral products of controlled fine particle size which meet exacting standards. Information is available.
28-28c *Minerals & Chemicals Philipp

Catalog.....36-page price catalog on essential oils, aromatic chemicals and specialties and certified colors includes short descriptions and uses of the various products.
323A Dodge & Olcott Inc.

Cerium Oxide.....Brochure describes a fast-acting glass-polishing oxide and a family of anti-foaming reagents developed for use with it. Composition and applications are listed.
323B Vitro Chemical Co.

Diatomite.....Celite offers constant uniformity in every grade to assure constant results and less downtime. Many different grades of Celite are produced. Information.
140 *Johns-Manville

Food Additives.....Booklet discusses the value of food additives, how they are developed and the precautions taken by industry and government to maintain safety.
323C Manufacturing Chemists' Assn. Inc.

Formamide.....32-page booklet presents the first comprehensive study of the chemistry and properties of chemical used in the synthesis of organic compounds.
323D E. I. du Pont de Nemours & Co.

Furfuryl Alcohol.....is a reactive solvent for epoxy resins catalyzed with boron trifluoride monoethylamine. Complete data and test reports in Bulletin 138.
95 *Quaker Oats Company

Ketone Peroxide Catalyst.....Bulletin discusses product containing 60% methyl ethyl ketone peroxide that is effective at low working temperatures in polyester resins curing.
323E
Lucidol Div., Wallace & Tiernan Inc.

Laboratory Chemicals.....Catalog contains over 5,000 laboratory listings, including organics, inorganic reagents and elements and a comprehensive line of stains and indicators.
323F Matheson Coleman & Bell

Methyl Parathion.....research report discusses a new stabilized form of chemical resistant to heat and hydrolysis and from catalytic degradation in absorbents contact.
323G Stauffer Chemical Co.

Organics.....can be manufactured to your specifications, in quantities from a few gallons to tank car lots. A more detailed outline in Bulletin K-6.
328 *Nalco Chemical Co.

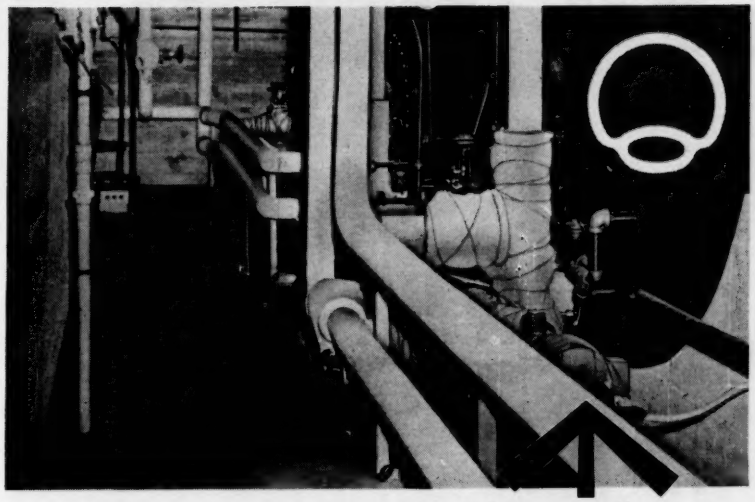
Oxygen.....Tonnage oxygen plants built and operated for your oxygen-nitrogen processes. No capital investment; you pay only for oxygen. Details available.
16-17 *Air Reduction Co.

Plastic.....Teflon is easily bondable to other materials and to itself with commercial adhesives. Complete Teflon service to help improve design & increase reliability.
337 *Raybestos-Manhattan, Inc.

* From advertisement, this issue

from ALCOA

good designs made better with aluminum



Globe Engineering installed Alcoa Unitrace system for piping paraffin and stearic acid . . . lowered fire hazard, increased production rate

Binney & Smith Inc., Winfield, Kansas, CRAYOLA® crayon manufacturer, recently effected cost savings with Alcoa* Unitrace piping, at one-eighth the quoted cost of stainless. Formerly, block paraffin had been melted slowly in holding pots. Now, Binney & Smith buys paraffin by tank carload, heats and pumps directly to underground storage. Stearic acid is also handled in the same system without discoloration. Fabricated and installed by Globe Engineering Co., Wichita, Kansas, the Unitrace system effected savings in purchasing, insurance, handling and production. Alcoa Unitrace is the light, strong, corrosion-resistant pipe that provides steam and product passages in a single extruded unit —eliminating costly external steam jackets or inefficient tracer tubes. Please send coupon for more information.

*Registered trademark of Aluminum Company of America

ALCOA ALUMINUM
ALUMINUM COMPANY OF AMERICA

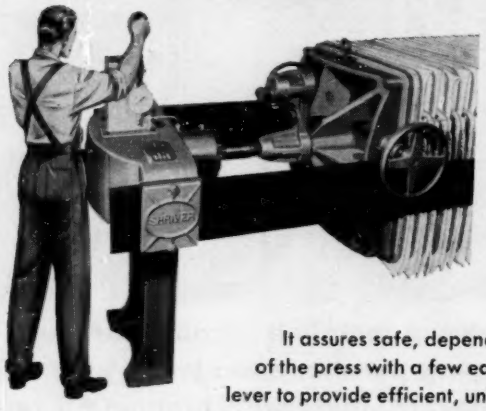
Aluminum Company of America, 825-T Alcoa Building, Pittsburgh 19, Pa.

Please send me the following literature covering Alcoa Aluminum for tubular products and other uses in the process industries.

☐ 34-10197 *Aluminum Pipe and Fittings*
☐ 34-10418 *Alcoa Unitrace: Combines Piping and Tracing in One Unit*
☐ DD- 514 *Alcoa Duotrace Technical Report*
☐ 68-10460 *Process Industries Applications of Alcoa Aluminum*

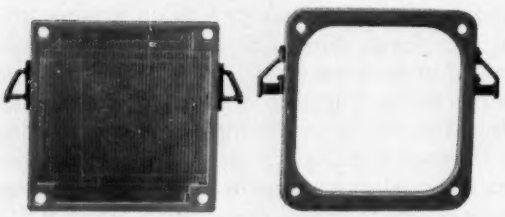
Name_____ Title_____
Company_____
Address_____
City_____ Zone_____ State_____

2 WAYS TO MODERNIZE YOUR FILTER PRESSES



Install a SHRIVER "HYDRO-KLOSER"

It assures safe, dependable one-man closure of the press with a few easy strokes of the pump lever to provide efficient, uniform closing pressure, reducing leakage. This simple, rugged, self-contained hydraulic ram can be readily installed on any filter press. Bulletin 136 on request.



Polyester plate and frame

Upgrade PLATES & FRAMES for longer usefulness

1—Niresist, while double the cost of cast iron, lasts 5 to 10 times as long because of its greater corrosion resistance.

2—Spray coating wood plates and frames with epoxy or polyurethane doubles or trebles service life.

3—Polyester (glass-reinforced) plates and frames are lightweight with a highly resistant filtering surface and the added advantage of low heat absorption. Usable at temperatures of 250°F.

Let us discuss these and other ways of improving filter press service.

FILTERS AND COMPLETE FILTER STATIONS TO MEET YOUR EXACT PROCESSING NEEDS

T. Shriver & Company, Inc.

802 HAMILTON STREET • HARRISON, N. J.

Sales offices in principal cities

LITERATURE . . .

Polypropylene.....Seilon Pro is a practically indestructible polypropylene. It is versatile in its many properties and tailor-made adaptability to your requirements.
290 *Seiberling Rubber Co.

Polypropylene Coloring.....Advantages of coloring natural polypropylene with color concentrates and techniques for achieving optimum dispersions given in Report #4.
324A Eastman Chemical Products Inc.

Silicone Anti-Foam.....Anti-Foam 60 kills foam without affecting the other properties of your process. Disperses instantly in aqueous systems. Sample.
311 *General Electric Co.

Silicone Defoamers.....and antifoamers are effective against even the most violent and persistent foamers. New 8-page brochure "ABC's of Defoaming" gives full data.
61 *Dow Corning Corp.

Sodium Borohydride.....assures purity in the manufacture of glycols. A new technical bulletin, just published gives details and is available on request. Bul. 509.
111 *Metal Hydrides, Inc.

Solvent.....New improved Varsol offers long-lasting freshness. Retains its efficient solvency even after long storage or many processings in your plant. Information.
59 *Esso Standard Oil Co.

Solvents.....Comprehensive chart provides a comparison of the physical properties of over 200 commercially available common organic solvents and includes technical data.
324B Solvents & Chemical Group

Stabilizer.....Attagel 30 makes high analysis liquid fertilizers possible. Gives a stable, pourable suspension which will retain its stability. Information.
28-29a *Minerals & Chemicals Philipp

Stable Rayon.....Bulletin covers characteristics and properties of a new stable rayon product, and includes comparison charts and tables relating test data.
324C American Viscose Corp.

Trimethoxyboroxine.....12 page bulletin describes properties, uses and handling of versatile chemical used as a metals fire extinguishant, a curing agent for epoxy resins etc.
324D Callery Chemical Co.

Vinylidene Fluoride Resin.....Kynar has unexcelled combination of properties: strength, formability, and corrosion resistance. Information, samples, technical aid.
103 *Pennsalt Chemicals Corp.

Construction Materials

Alloy.....Bulletin "Engineering Properties of Ni-o-nel" describes composition, physical and chemical properties & includes detailed information on applications.
52 *The International Nickel Co.

Alloys.....Two grades of Kennametal provide answers to difficult corrosion-wear application. A booklet, "Proven Uses of Kennametal" is available.
R335 *Kennametal, Inc.

* From advertisement, this issue

Carbon Brick.....linings provide long service life in tough corrosion applications. For tanks, reactors, drain troughs & sumps. Information in Catalog Section S-6215.
79 *National Carbon Company

Coating Clay.....Spray-dried Kaolins offer high-purity and high-uniformity. Used for coating paper but are applicable to other applications. Information.
28-29b *Minerals & Chemicals Philipp

Coating Resin.....Plaskon coating resin is quality controlled to assure a more uniform pattern and freedom from mottling. More complete details are offered.
265 *Allied Chem., Plastics Div.

Coatings.....Nokorode coatings and their applications, uses and specifications are described in a technical booklet which is available on request.
122 *Lion Oil Co., Div. of Monsanto

Gasket Material.....Booklet describes "Armalon" felts & includes data on characteristics, detailed list of specific applications, & information on sizes & thicknesses.
171 *E. I. Du Pont

Dye-Solvent Carrier.....Cyanatex dyeing assistant EM dye-solvent carrier speeds penetration of dye. Further information is available on request.
8-9c *American Cyanamid Co.

Epoxy Resin Catalysis.....Diallylmelamine provides fast cure for epoxy resins above 130 deg. C, coupled with outstandingly long life at room temperature. Inform.
8-9b *American Cyanamid Co.

Insulating Firebrick.....35-page illustrated bulletin contains a complete discussion of the advantages on insulating firebrick as well as a wide variety of applications.
325A Babcock & Wilcox

Insulation.....Blanket insulations are factory fabricated to rigid specifications to assure efficiency. A free sample may be had upon request.
134 *Eagle-Picher Company

Mortars.....Polysulfide-base mortars provide a smooth or skidproof surface, as desired and are ready for traffic in less than one day. Brochure FC-100 is available.
128 *Thiokol Chemical Corp.

Packing Sets.....New low gland pressure TFE Teflon packing sets used for valves, heat exchangers and other static & semi-static applications. Bulletin CP-552.
R353 *Chemical & Power Products

Pipe Insulation.....Snap-On is the only one-piece pipe insulation available in sizes from copper tubing to 36" IPS. More complete information is available.
295 *Gustin-Bacon Mfg. Co.

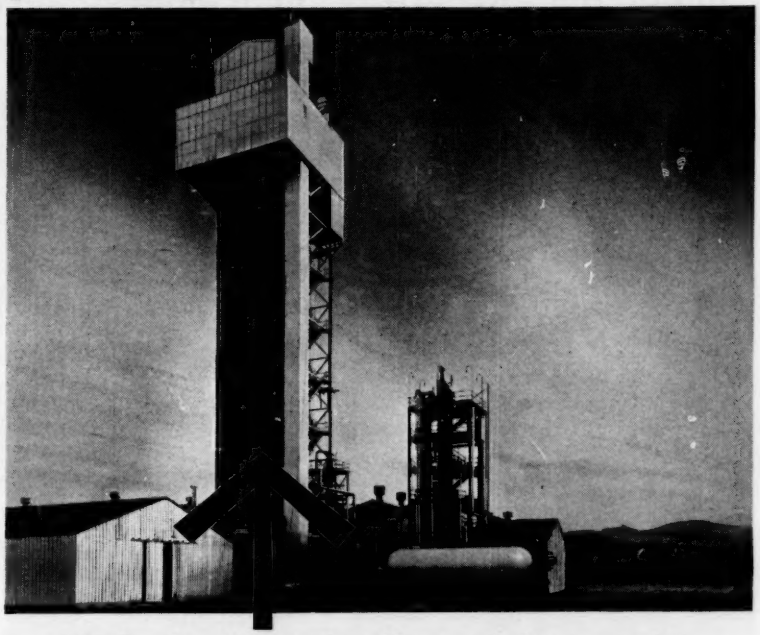
Platinum Metals.....in all shapes and forms . . . sheet, strip, foil, wire, tubing, gauze, salts & chemicals. Clads & Composites also available in many forms. Bulletin P-6.
261 *J. Bishop & Co.

Polyester Resin.....Laminac polyester resin fights off acid. Costs less to solve corrosion problems. Further information is available on request.
8-9a *American Cyanamid Co

* From advertisement, this issue

from ALCOA

good designs made better with aluminum



All-aluminum construction resists corrosion, weatherproofs thermal insulation in Spencer Chemical prilling tower

This 180-ft, all-aluminum, urea prilling tower, operated by Spencer Chemical Co., Henderson, Ky., was built by Mississippi Valley Structural Steel Co., St. Louis, Mo. To ensure uninterrupted, corrosion-free service, plant designers used Alcoa® Aluminum throughout—frame, walls, bolts, piping, fittings, connections and fasteners. Aluminum sheathing weatherproofs thermal insulation on tower, heat exchangers and piping. Please send the coupon for more information about Alcoa Aluminum's unique advantages.

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ALUMINUM COMPANY OF AMERICA

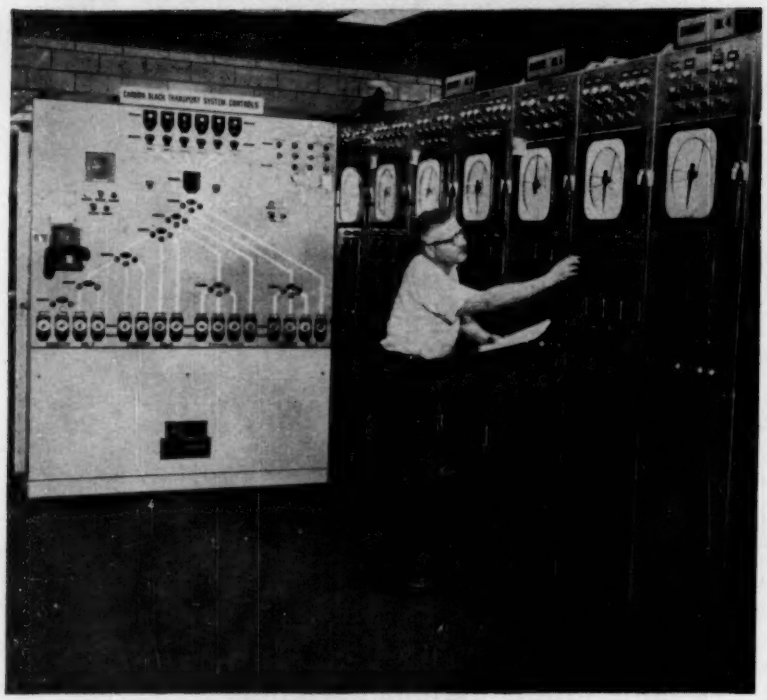
Aluminum Company of America, 825-F Alcoa Building, Pittsburgh 19, Pa.

Please send me the following literature covering Alcoa Aluminum for tubular products and other uses in the process industries.

☐ 68-10460 *Process Industries Applications of Alcoa Aluminum*
☐ 03-19122 *Alcoa Structural Handbook*
☐ 42-20849 *Resistance of Aluminum Alloys to Weathering and Resistance of Aluminum Alloys to Chemically Contaminated Atmospheres*

Name_____ Title_____
Company_____
Address_____
City_____ Zone_____ State_____

How The Goodyear Tire & Rubber Company gets **QUICK-CHANGE FORMULATION for Carbon Blacks and Oils**



WITH RICHARDSON SELECT-O-WEIGH

A turn of the dial sets up the formula...that's all Goodyear has to do, and automatically Richardson-engineered uniform-flow feeders and scales measure out precise amounts of hard-to-handle carbon blacks to another batch of tire stock in the Banbury. Then oils are added from heated holding tanks loaded by steam-jacketed automatic scales. No time-consuming, error-prone manual compounding...no messy spillage...no health hazards when Select-O-Weigh controls the batching. In addition, the system supplies *full Banbury control* and routes all the carbon blacks through the plant.

Whether it's quick-change formulation for rubber or other products, Richardson know-how in all kinds of process automatic weighing assures reliability...the ability to stand the gaff of day in, day out plant operation. Apply this know-how to your batching system. Write or phone **Richardson Scale Company, Clifton, N. J.**

RS-5

Send for free technical bulletin

Richardson

Sales and service Branches in Principal Cities. Also manufactured in England, France and Australia. Richardson Scales conform to U. S. Weights and Measures H-44 for your protection.

MATERIALS HANDLING BY WEIGHT SINCE 1902

LITERATURE . . .

Protective Coatings.....for steel tank linings, concrete floors, tank cars, etc. Selection of coatings & other Plasite products covered in booklet.
L313* Wisconsin Protective Coating Co.

Resinous Grout Cement.....Supertite adds years of service to both new and old floors and eliminates contamination problems. Information available on request.
271 *Amercoat Corporation

Rubber.....Enjay Butyl HT 10-66 is halogenated for high heat resistance, convulcanization with other elastomers. Write for Technical Manual HT 10-66.
34-35 *Enjay Chemical Company

Steel.....Type 2 aluminized steel is ideal for drying and processing ovens because it is two metals in one with a unique combination of properties.
284-285 *Armco Steel Corp.

Tank Linings.....New Gar-Line Penton linings offer high-temperature protection against corrosion. Data on Penton; information on tank linings.
138 *Garlock Inc.

Tile.....Acid-proof Duro tile for the most durable chemical resistant floors. It is dense and non-absorbant throughout the entire thickness.
159-160 *Harbison-Walker Refractories

Wire Cloth.....for corrosive service, with accurate mesh count, close tolerance wire diameter, precision weaving, etc. Bulletin FC is available on request.
304 *Newark Wire Cloth Co.

Electrical & Mechanical

Air Motors.....feature seven unique benefits—variable speed, explosion-proof, can't burn out, operates in any position, withstands heat, reversible & compact. Cat.
TL353 *Gast Mfg. Co.

Diode.....Brochure "Introduction to the Shockley 4-Layer Diode" discusses operation and application and includes a dozen basic circuit application schematics.
326A Shockley Transistor

Drive, Tube Expander.....Air-Magnetic drive is setting new records for speed and accuracy. Standard model handles most jobs—heavy duty for higher torque. But. Y-53.
289 *Elliott Company

Electrical Machinery.....Newly revised 48-page "Catechism of Electric Machinery" presents the most important theoretical and practical features of the most common types.
326B Fairbanks, Morse & Co.

Gas Turbines.....Full details on how 305 gas turbines can bring you lower first cost, reduced floor space & installation costs in Bulletin 186.
143 *Clark Bros. Co.

Gear-Driven Swivel Joints.....are available in 2, 2½, 3 and 4 inch sizes. There is a size and type to meet every requirement. Full catalog and price information.
107 *Continental-Emsco Co.

* From advertisement, this issue

Gearmotor.....has ratings ⅛ to 125 hp. in right angle, parallel or in combination. Right angle ratios are available in 96:1; parallel 120:1. Bulletin E2409 is offered.
14-15a *Reliance Electric & Engrg. Co.

Motodrives.....Reeves motodrives are used extensively for hundreds of production needs. Available in hundreds of space-saving assemblies. Bulletin M-592.
14-15c *Reliance Electric & Engrg. Co.

Motor.....TEIGF motor provides protection against expensive operation. Gas loss is lower than commercial standards. Further information is contained in Bul. 226.
144 *Electric Machinery Mfg. Co.

Motor.....Encapsulated motor gives you positive protection from dust, dirt, acid and water. Maximum flexibility, tensile & bond strength. Further information in Bulletin B-2108.
14-15b *Reliance Electric & Engrg. Co.

Motor Control Center.....features reliability, versatility, economy, strength and safety. Exclusive plug-in terminal blocks cut installation time. Facts.
129 *Allis-Chalmers

Motor Starters.....A new line of Bulletin 709 motor starters are the greatest advance in motor control in thirty years. More information is available.
139 *Allen-Bradley

Motors.....Crocker-Wheeler motors, from smallest to largest, are offered in all conventional enclosures and modifications with insulation to suit the application.
150 *Elliott Company

Power Panelboard.....QMB panelboards accommodate reversing or non-reversing starters, plug-in circuit breakers & plug-in switches. The complete story is offered.
53 *Square D Company

Rupture Discs.....are available in sizes ranging from ⅛" to 44" in diameter, covering rupture pressures from 3 to 100,000 PSI. Information on request.
300 *Black, Sivalls & Bryson, Inc.

Speed Reducers.....Helical worm gear speed reducers include a conventional worm & gear plus an auxiliary set of helical gears on the input shaft. Cat. No. 45-D.
36 *D. O. James Gear Mfg. Co.

Speed Variator.....New space-saving motorized speed variator assures constant H.P. and constant Torque loads. Engineering information in Bulletin 275.
63 *Cleveland Worm & Gear Div.

Steam Turbine-Generator.....Complete information on types and ratings from 2000 kw to the largest is contained in Bulletins 7654A & 9448 which are offered.
48-49d *Allis-Chalmers

Switchgear.....Advanced design features of 600-volt switchgear with K-Line circuit breakers described in 20-page bulletin that provides information on circuit breakers.
327A I-T-E Circuit Breaker Co.

Transformer.....A compact 50/60 cycle variable transformer series having output ratings up to 3.75 amperes with constant current loads is described in bulletin P6121.
327B Superior Electric Co.

* From advertisement, this issue

from ALCOA

good designs made better with aluminum

Alumi-Louvers provide dependable, economical ventilation at New York State Natural Gas Co.

For uninterrupted, maintenance-free performance, Mansfield Metal Fabricating Co., Mansfield, Ohio, constructs its famous *Alumi-Louvers* of Alcoa® Aluminum. A typical installation (shown) is at New York State Natural Gas Co., Tamarack, Pa. *Alumi-Louvers* require no maintenance, provide dependable, economical control of ventilation and temperature. Mansfield reports that lightweight aluminum cuts transportation and installation costs (special rigging is unnecessary). For more information about corrosion-resistant aluminum, please send the coupon.

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ALUMINUM COMPANY OF AMERICA

Aluminum Company of America, 825-TT Alcoa Building, Pittsburgh 19, Pa.
Please send me the following literature covering Alcoa Aluminum for tubular products and other uses in the process industries.

- ☐ 68-10460 *Process Industries Applications of Alcoa Aluminum*
- ☐ 42-20849 *Resistance of Aluminum Alloys to Weathering and Resistance of Aluminum Alloys to Chemically Contaminated Atmospheres*
- ☐ 61-21088 *Aluminum Cooling Towers and Their Treatment*
- ☐ 34-11566 *Alcoa Aluminum Heat Exchanger Tubes*

Name_____ Title_____
Company_____
Address_____
City_____ Zone_____ State_____

ELIMINATE

CHEMICAL WOBBLE

with NALCO® Organics

A peg that almost—but not quite—fits a hole will wobble when placed in that hole. The same principle applies to organic processes. An organic chemical *may* be applicable (to one degree or another) in a given process. But if it doesn't fit the process exactly, the result is "chemical wobble".

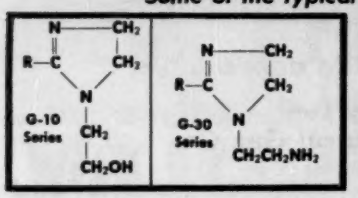
The way to avoid chemical wobble in *your* processes is to use a custom made organic, manufactured specifically to meet your individual requirements. And when you need custom made organics, Nalco Chemical Company is the place to look for them.

Nalco has already helped many manufacturers eliminate chemical wobble, supplying them with specific organics to meet specific needs. (Don't ask what they are, however—Nalco keeps all customers' requirements, and the nature of the organics made for them, in strict confidence.)

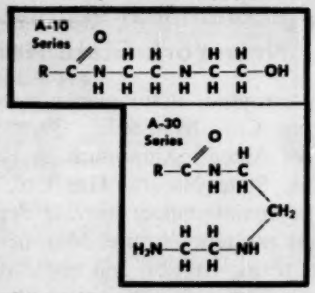
In many cases, the manufacturer had to do no more than submit his requirements to Nalco. Nalco researchers then developed the exact chemical to meet his needs, and also determined the most efficient and economical method of manufacturing it.

Nalco organics include surface active agents, film-formers, emulsifiers, and dispersants. Among their many uses, they are suitable for corrosion inhibitors, bactericides, antistatic agents, plasticizers, flotation reagents, pigment grinding and flushing aids, wetting agents, and foaming agents. Many are also specific chemical intermediates.

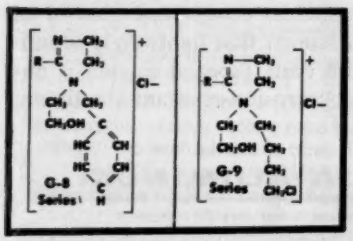
Some of the typical Nalco organics:



Fatty Imidazoline Monoamines and Diamines — (*Nalcamine*® G-10 and G-30 series) derived from various fatty monocarboxylic acids and polyamines.



Fatty Amidomonoamines and Amidodiamines—(Nalcamine A-Series Products) derived from fatty monocarboxylic acids (C_6 C_{18}) and polyamines.



Quaternary Ammonium Chlorides — derived from various Nalcamine products.

Oxyalkylation products. These include adducts of abitol, castor oil, alkyl phenols, phenolic resins, tall oils, and fatty amides, polyalkanol polyamines, and polyglycol monoethers.

These organics, and many others, can be manufactured to your specifications, in quantities from a few gallons to tank car lots. When you need a specific chemical *to eliminate a wobble* in your processes, call on Nalco.

Further information, technical data, and samples of the materials mentioned here are available on request. For a more detailed outline of Nalco organics, write for Nalco Bulletin K-6.

NALCO CHEMICAL COMPANY

6236 West 66th Place **Chicago 38, Illinois**

Subsidiaries in England, Italy, Mexico, Spain, Venezuela and West Germany

In Canada—Alchem Limited, Burlington, Ontario

Nalco®

... Serving Industry through Practical Applied Science

Nalco CHEMICALS

LITERATURE . . .

Turbines.....built to customers' specifications, including API and NEMA standards. A complete range from 1 HP to 250 HP. Further facts in Catalog 200.
127 *Coppus Engineering Corp.

Turbines, Solid-Wheel.....seldom see down time because of bonus reliability built into each turbine. Further details are contained in Bulletin S-116.
136 *Terry Steam Turbine Co.

Handling & Packaging

Air & Gas Handling.....Equipment for efficient & economical cleaning and handling of air and gas. Further information on the products of interest.
R313 *Aerotec Industries, Inc.

Bag Closing Equipment.....on the production line or one at a time. A complete line ranging from portable to fully automatic production line machines. Catalog.
T299 *Dave Fischbein Co.

Conveyor Belts.....Metal-mesh belts for such diversified operations as bagging cement, drying wool, etc. A 130-pg. Reference Manual gives specifications, etc.
64 *The Cambridge Wire Cloth Co.

Lift Truck.....A gas lift truck saves on initial price, saves on maintenance and saves on operating costs. With cushion rubber tires or pneumatic tires. Details.
75 *Automatic Transp. Co.

Pneumatic Conveying Systems.....New bulletin M-260 discusses types of systems, illustrates & diagrams high and low density arrangements. Shows equipment & gives all details.
283a *The Day Co.

Pressurized Transports....Can be fabricated of any material including T-1 steel, or various other steels. Complete specifications available.
4 *Pressed Steel Tank Company

Scales.....feature no knife edge pivots to wear & cause inaccurate weighing. Information is available on bagging, batching, metering and checkweighing scales.
L335 *Thayer Scale Corp.

Screw Elevator.....Rotor Lift features compact, single leg design which saves space & avoids large openings in overhead floors. Engineering Catalog is available.
L294 *Southwestern Supply & Machine

Storage Tanks.....A 12 pg. bulletin describes horizontal & vertical storage tanks. Filled with photos of various installations plus description of auxiliary equipment.
283b *The Day Co.

Tanks.....Poxyglas tanks are 3 to 4 times as strong as conventional reinforced plastic tanks. Lighter than welded steel tanks. Corrosion-resistance chart is offered.
39 *Black, Sivalls & Bryson

Tractor Shovels.....Michigan Tractor Shovels are available in a wide variety of models for excellent performance and economy. Further information is available.
267 *Clark Equipment Co.

* From advertisement, this issue

Air Operated *Jacketed* PLUG VALVES

BEATS MANPOWER *every time*

ROTARY TYPE

Parks-Cramer jacketed plug valves can now be supplied for air or hydraulic operation. Actuators are either cylinder or rotary type depending on degree of rotation, torque and indexing sequence required.

Multiport valves can be arranged to stop at any predetermined position, and to proceed from one position to another in any sequence manually or automatically.

Remote control stations with port position indicating lights can be supplied as required.

For hazardous locations, explosion proof accessories can be furnished.

Actuators are mounted directly on the valve—brackets or bracing from adjoining pipe or building is not required. Linkage to valve stem is direct through couplings or levers—clumsy rack and pinion gearing not needed.

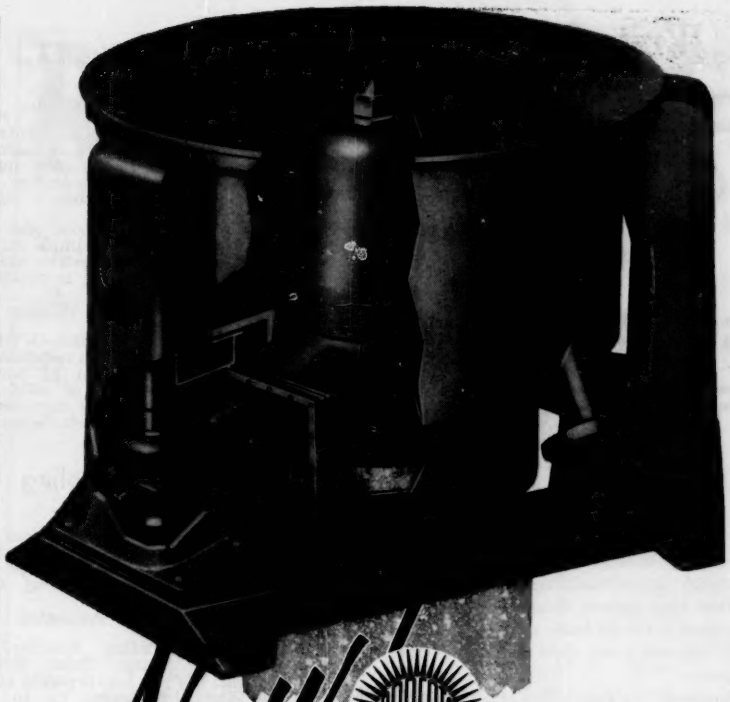
For complete description, details and dimensions, send for our new catalog supplement 356-S.

CYLINDER TYPE

D

For complete description, details and dimensions, send for our new catalog supplement 356-S.

Parks-Cramer Company
FITCHBURG 13, MASSACHUSETTS



Now! the ROBERTS LS/SC

a Link Suspended, Stationary Curb centrifugal machine which provides a combination of features long wanted by the Chemical Process Industries.

Features . . . Link Suspension! No metal to metal moving parts. No lubrication. Soft lateral movement. No vertical movement. Effective damping. This suspension isolates dynamic parts from curb and foundation and reduces vibration to an astonishing low.

Features . . . Stationary Curb! With rigid feed, wash, effluent, and solids-discharge connections. No vibration damage to curb mounted accessories. Extends bearing life by reducing bearing loads. Increases personnel safety. Provides rapid drainage, more effluent capacity.

Features . . . Direct Coupled Hydraulic Motor! No belts. Compact. Light weight. Provides power for exclusive, slow speed, reverse discharging. Provides adjustable loading speed and adjustable top speed. Hydraulic braking (even at power failure). No brake linings to wear. Constant horsepower drive reduces peak electric loads.

Features . . . Oversize Anti-friction Bearings! Basket spindle bearing housing is air purged. This feature, designed to protect bearings from damaging effects of process material environment, also provides a convenient means for introducing controlled atmosphere within the basket. Can be grease lubricated while in operation. No-belt design — no belt-pull-loading on the bearings.

2905

Investigate its potential in relation to your operation. We will welcome the opportunity to co-operate with you.

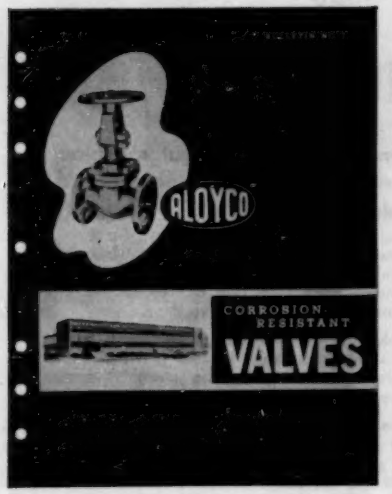
ROBERTS STEVENS
The WESTERN STATES MACHINE COMPANY
1700 Fairgrove Avenue
HAMILTON, OHIO, U.S.A.

Write for this

COMPLETE GUIDE TO ALOYCO CORROSION RESISTANT VALVES

It quickly tells you what's available in Aloyco's line of stainless steel and high nickel alloy valves. Cross section illustrations cover 48 basic designs in pressure classes from 150# through 1500# services.

Included is a tabulation of alloy availability by design, and the complete analysis for each material offered. Also



outlined are engineering standards and adaptable features for standard valves.

This brochure summarizes Aloyco's 30 years of specialized experience in the design, development and manufacture of stainless steel valves. Write: Alloy Steel Products Company, 1301 West Elizabeth Ave., Linden, New Jersey.

1.3

Longer Lasting ALOYCO VALVES

ALLOY STEEL PRODUCTS COMPANY

LITERATURE . . .

Truck Scales.....Type "S" Truck Scales are extremely accurate... famous for accuracy, low maintenance, best load distribution, minimum installation requirements.
263 *Fairbanks Morse

Vibratory Feeders.....Low cost air vibratory feeders are simple in design and offer trouble-free operation. A feeder catalog is available on request.
BL353 *National Air Vibrator Co.

Weighing System.....Select-O-Weigh governs all components required for automatic formulation by weight of a product, liquid or solid, involving any number of ingredients.
326 *Richardson Scale Co.

Heating & Cooling

Air Preheaters.....Ljungstrom air preheaters improve combustion, make fuel burn more completely. Additional information on their uses is available.
148 *The Air Preheater Corp.

Boilers.....Bulletins describe the Modulatic Water Tube Boilers. Furnish high or low-pressure steam (at design pressures up to 1000 psi, or even higher).
69 *Vapor Heating Corp.

Gradiation Heating.....for batch processing a long list of heat-sensitive materials. Complete details on this system may be had upon request.
R357 *Selas Corp. of America

Heat Exchanger.....Stainless steel extended surface heat exchangers can be designed to your performance specifications. Further information is offered.
71 *Marlo Coil Co.

Heat Exchangers.....Transaire Air-Cooled units are now being used in many varied processing operations. Feature the exclusive Aimco fin-tube.
173 *Yuba Consolidated Industries

Heat Transfer.....Platecoil provides a packaged answer to many heat transfer problems, avoiding costly engineering and fabricating of pipe coils. Bulletin P61.
60 *Platecoil Div., Tranter Mfg., Inc.

Rotating Seal.....There is a standard type and size Rotary Union for heating & cooling any revolving roll or drum. Pipe sizes ¼" through 5". Bulletin 700.
L307 *Perfecting Service Co.

Silicon Rectifiers.....for large electrochemical & industrial applications. These rectifiers employ water-to-water heat exchanger equipment. Details.
48-49b *Allis-Chalmers

Steam Traps.....Series 60 Impulse steam traps are designed with high production in mind. The latest steam trap Bulletin T-1743 is available on request.
55 *Yarnall-Waring Company

Temperature Controls.....A handy, condensed catalog of the complete line of temperature controls & allied equipment for industrial heating & refrigeration.
157 *The Partlow Corp.

* From advertisement, this issue

ERIEZ *Magnetic Minute*

60 seconds that will help you improve operating efficiency.

Here's POWERFUL PATENTED MAGNETIC PROTECTION for LIQUID PROCESSING EQUIPMENT

Handling liquids or slurries? Permanent Magnetic Ferrous Traps by Eriez protect against fine iron and tramp iron contamination to —

- Help assure product purity.
- Reduce damage and maintenance to filters, mixers, pumps, etc.
- Eliminate clogging and production slow-downs.

In the full line of Eriez Ferrous Traps there's a standard or sanitary model for your application... ideal for use with foods, chemicals, ceramic slips, hydraulic oil lines, etc. All models offer these characteristic benefits:

- Rugged cast one-piece bodies that easily withstand working pressures up to 150 psi.
- Clean, simple design — no moving parts.
- Magnetic element handles materials with temperatures up to 850° F.
- Easy to inspect and clean; magnetic element lifts from the body in seconds.

For technical and application data write to:

ERIEZ MANUFACTURING CO.
74T Magnet Drive, Erie, Pa.

MAGNA-THOUGHT

Our greatest source of satisfaction is the acceptance our products have earned through superior performance and dependability.

M. L. CRAMER
Office Sales Manager

ERIEZ

A GROWTH COMPANY...
10 NEW PRODUCTS IN THE LAST 5 YEARS

LITERATURE . . .

Vaporizers.....offer unusually sensitive heat control by eliminating flash-down to achieve precise final temperatures. Feature fewer control devices.
151 *Foster Wheeler Corp.

Pipes, Fittings & Valves

Hose & Pipe.....Teflon-lined rubber hose & Condor acid hose are available with rubber, neoprene, Butyl or Hypalon tube as needed along with Condor flexible pipe.
50 *Raybestos-Manhattan Inc.

Joints & Loading Arms.....Steam jacketed joints and jacketed loading arms are available in a complete range of sizes. Specific details are available on request.
68 *Chiksan Company

Ball Valves.....engineered for superior flow control and minimum maintenance operation. Complete information on the line of ball valves in Brochure ADB 1001.
137 *Crane Co.

Connectors.....A general catalog describing the line of pressure vessel connections available in detail may be had upon request to help solve problems.
T356 *Lenape Hydraulic Press. & Forg.

Diaphragm valve.....Air-operated diaphragm valve features wide range of operator sizes, drip-tight shutoff, types for every job. Bulletin 134.
255 *Hills-McCanna Company

Fittings.....Forged steel fittings are available along with Weldolets, Thredolets, Sockolets, Elbolets, etc. A most useful forged steel fitting catalog, No. FSF-2-1961.
274 *Bonney Forge & Tool Works

Pipe.....safely handles 94% of known corrosive solutions. It is lightweight and no painting or maintenance is necessary. Further details are available.
153 *Fibercast Company

Pipe.....Saran Lined Pipe, fittings, valves and pumps are available for systems operating from vacuum to 300 psi, from below zero to 200 F. Information.
174 *Saran Lined Pipe Co.

Pipe and Fittings.....A bulletin, No. J-56 describing jacketed pipe and fittings in detail has been prepared and is available on request.
T354b *Hetherington & Berner

Piping Chart.....17" x 11" pipe dimension chart shows outside diameter and wall thickness for all sizes of pipe from ½" to 42" and is suitable for desk or wall mounting.
331A Midwest Piping Div.

Spray Nozzles.....Complete and accurate performance data for each of the hundreds of spray nozzles in the Spraco line has been prepared & is available on request.
296 *Spray Engineering Co.

Spray Nozzles.....Catalog 24 is the most comprehensive catalog ever printed. Spray nozzles are completely described and the catalog is fully illustrated.
T352 *Spraying Systems Co.

* From advertisement, this issue

REVERSIBLE!

One of many VIKING pumping advantages

- Operate Equally Well in Either Direction
- Prime Themselves Fast
- Just 2 Moving Parts
- Deliver Thick or Thin Liquids
- Smooth, Even Discharge

AVAILABLE IN
- Iron
- Bronze
- Stainless Steel
- Ni-Resist
- Steel
- Ductile Iron
- Other Alloys

- Available in 22 Sizes — ½ to 1050 G.P.M.
- 850 Catalogued Models. Thousands of Special Pumps.
- Pressures Up To 100 P.S.I. with non-lubricating liquids
  . . . 200 P.S.I. with lubricating liquids
  . . . 500 P.S.I. with hydraulic oils

For additional information, ask for catalog 615C

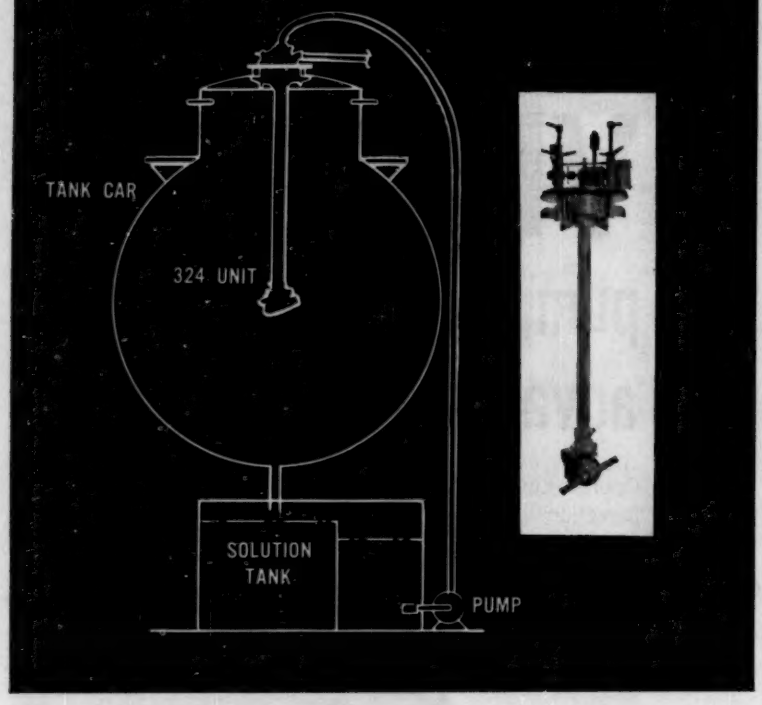
VIKING PUMP COMPANY

Cedar Falls, Iowa, U.S.A.
In Canada,
It's "Roto-King" Pumps"

50 YEARS

See Our Unit
In Chemical
Engineering Catalog

Another job done better through OAKITE ECP*
Engineered Cleaning Program



Tankers cleaned in under 4 hours ...without sending a man inside

An Oakite Engineered Cleaning Program is comprehensive. It not only provides specialized chemical materials to dislodge, dissolve, or disintegrate the soils, but also mechanization of the job where feasible. Take a case of cleaning out tankers and tank trucks, for example.

One processor had a particularly tough problem removing resin-type soils from such equipment. It was being done the hard way—by boiling with caustic soda, then manually scraping. It was messy, tedious, took up to 48 hours to do.

The Oakite program, developed in cooperation with plant personnel, made short work of the job. It took advantage of the power, speed and efficiency of an Oakite Interior Tank Cleaning Unit Model 324 to hurl a hot spray of Oakite 24 solution on the soils for 1½ to 2½ hours. Same unit then rinsed. Even the dirtiest tankers were cleaned in under 4 hours. And no one had to scramble in to scrape or brush any residues. What's more, there was also a 25% saving in cost of materials over former method.

*Oakite ECP is a comprehensive cleaning program engineered to fit your particular operation. The program details methods, materials, procedure and suggests a time-table for each of your cleaning problems. Since product-residue soils in processing industries are so diverse, the Oakite man works in cooperation with your own engineering people in drafting his specific recommendations. He has over 170 specialized materials to choose from. He lends his experienced supervision to see the jobs through. Exceptional soils are referred to the Oakite Research Laboratories for analysis and advice. Send for details. Write Oakite Products, Inc., 16H Rector Street, New York 6, N. Y.

OAKITE
over 50 years' leadership in industrial cleaning
Est. 1909
SCIENCE

LITERATURE . . .

Stainless Tubing & Pipe.....A new selecting and buying guide, Bulletin 128, is available on request detailing the advantages and applications of stainless tubing & pipe.
22-23 *The Carpenter Steel Company

Tubes.....Condenser and heat exchanger tubes are available in over 50 metals and alloys along with Duplex tubes in various materials. Further information is offered.
162 *Bridgeport Brass Co.

Tubing.....A full-range selection of seamless and welded stainless tubing is available. Details are contained in Bulletin T-148 which is available on request.
123 *Babcock & Wilcox

Tubing, Flexible Metal.....Sales Engineering Consulting services that follow through from original design to finished product are available to solve tubing problems.
142 *Anaconda Metal Hose

Tubing, Heat Exchanger.....offers high quality at lower cost. Information on welded steel and stainless steel heat exchanger tubing is contained in Brochure No. 5.
176 *The Standard Tube Co.

Unions.....have the hardness differential which assures fast, easy make-up, tight seal & freedom from galling. Four different seat types. Facts are offered.
276 *Rockwood Sprinkler Co.

Valve.....Sampling valves assures perfect sealing by two compressible replaceable Teflon rings. A new catalog page is available for further information.
T278 *Strahman Valves, Inc.

Valves.....A complete guide to Aloyco corrosion resistant valves is available on request. It contains a tabulation of alloy availability by design & complete material analysis.
L330 *Alloy Steel Products

Valves.....for the control of hot, cold, erosive, corrosive or viscous fluids. Designed to accept all standard actuators. General Catalog 1500-E is available.
179 *The Annin Company

Valves....Eccentric-action plug valves are the most dependable, complete valves for almost every type of service. A catalog is available on request.
70 *DeZurik Corp.

Valves.....for fast, easy opening and closing with a leak-proof seal & straight-through flow with minimum pressure drop. Informative bulletin is available.
105 *Everlasting Valve Co.

Valves.....Safety Relief valves have a special "O" ring seat seal that stops leakage completely. Available in both Standard & Balanced Bellows design. Bul. 1940.
66 *Manning, Maxwell & Moore, Inc.

Valves.....Operation from full-open to full-closed is accomplished in one-half second with these noncorrosive ball valves made of plastic. Information.
169 *Kraloy-Chemical Co.

Valves.....Forged steel valves are available on all lines up to 2 in. Designed to meet control requirements with minimum replacement & maintenance. Information.
161 *Ohio Injector Co.

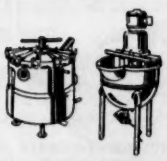
* From advertisement, this issue

GROEN

STEAM JACKETED KETTLES

meet every processing and mixing need!

The contrast between kinds of products, where a cook-mix process is employed, staggers the imagination. We frankly don't know how many industries require this type of processing. But if you have a need for minutely controlled temperatures for either heating or cooling combined with thorough mixing or agitating, Groen steam jacketed kettles provide the most efficient method ever developed. Groen engineering research brings you unexcelled heat transfer faster, easier, with substantial savings in time and labor. Groen stainless steel processing vessels are easier-to-clean, too, providing the ultimate in sanitation. There's a size and type for every process or product. Write for complete engineering data and specification sheets.



Complete line includes tanks, coils, vacuum kettles, revolving pans, tubular heat exchangers, pilot plant units and special specification equipment.

GROEN MFG. CO.

1900 Pratt Blvd., Elk Grove Village, Ill.
1377 Palasade Ave., Teaneck, N. J.

SERIES 300 PROPORTIONING PUMPS

ADJUSTABLE IN OPERATION FROM ZERO TO FULL CAPACITY

The unique control mechanism on American's new 300 Series Pumps provides full range adjustment while the pump is operating. Capacities range from 1 to 812 gallons per hour on the simplex series and from 2 to 1624 gallons on the duplex series. Maximum working pressure is 10,000 PSI. For maximum versatility and absolute minimum maintenance the Series 300 also incorporates these quality American design features:

- **Interchangeable liquid ends.**
- **New cam adjustment mechanism controls pump plunger stroke from any point from zero to maximum output.**
- **Compact housing — all moving parts enclosed.**
- **E-Z Clean Cartridge Valves for simple maintenance.**
- **Plunger (diameters from ¼" to 2¾") serviceable without disturbing the adjustment mechanism.**

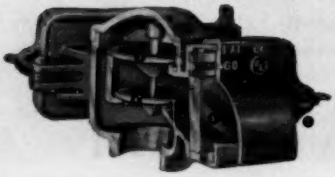
For use in high-corrosion environments, new Series 300 American Pumps are available with plungers and liquid end made in either ceramics, chrome plate or stainless steel. Remote or automatic controls are also available. Write American Meter Company for full details.

AMERICAN® METER COMPANY
INCORPORATED ESTABLISHED 1836
pump division
13500 PHILMONT AVE. PHILADELPHIA 16, PA.

Protectoseal conservation Vents incorporate unique design and operating features to ensure optimum service on flammable or hazardous liquid storage tanks of every type.

● FLAME ARRESTER DESIGN

Vertically mounted rectangular p... ype flame arrester structure is *outside* the housing. Advantages:



1 Pressure tight Aluminum alloy casting
2 Wing Nut on Swing Bolt
3 & 4 Pressure and Vacuum Relief Valves
5 Flame Arrester Structure

1. In the event of fire, the vent burns *at the arrester*, rather than at the valves. This eliminates heat warping or distortion of the valve mechanism.
2. Dirt and other foreign particles cannot reach valves, to cause improper seating.
3. Flame arrester is exposed to corrosive vapors on exhale cycle only. This keeps arrester plates clean longer, requires less maintenance.
4. Self-drainage of condensate.

The interchangeable flame arrester structure is made of heavy gauge metal to resist damage, bending or warping. Accurate, positive air-spacing assured upon re-assembly by embossings on the face of each plate.

A spare arrester can be inserted to safeguard tank interior while original arrester is being cleaned and serviced. Loosening wing nut and pushing swing bolts aside permits quick, easy removal of flame arrester structure.

Pressure and vacuum relief valves in Protectoseal Conservation Vents may be fabricated to relieve at settings required by your operating conditions. When severe corrosion is present, the vent housing, valves, and flame arrester structure may be fabricated from special corrosive-resistant metals. Teflon valve seats may also be provided.

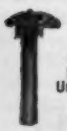
Conservation Vents are made in a range of sizes to meet virtually any requirement. UL and FM approved.

OTHER PROTECTOSEAL EQUIPMENT FOR STORAGE TANK OPERATION

End-of-Line Flame Arrester Vent

In-Line Flame Arrester Vents

Steam Jacketed Vent with Flame Arresters



Combination Fill and Vent Units, Fill Units

Combination Vent Rodding and Sampling Units

Emergency Relief

Write for the Protectoseal Blue Book. Illustrates and describes complete line of Protectoseal Products for hazardous liquid storage tank application.

THE PROTECTOSEAL COMPANY
1948 SOUTH WESTERN AVE. • CHICAGO 8, ILLINOIS

LITERATURE . . .

Valves.....feature longer life—six, eight, even ten times ordinary types. Sealant systems replaces the seat from the outside. Information in Bulletin V-618.
131 *Rockwell Mfg. Co.

Valves, Ball.....with Teflon or rubber seats. Feature larger waterway diameter, spring-loaded ball seats, ease of maintenance and reliability. Details.
277 *Rockwood Sprinkler Co.

Valves, Gate.....Special stainless steel gate valves are meeting the most precise demands of nuclear services. Detailed information is available.
58 *Darling Valve & Mfg. Co.

Valves, Lubricated Plug.....available in either full or reduced port; rectangular, round, diamond & V-ports; also venturi, multiport & steam jacketed models. Cat. 400.
145 *W-K-M Div. of ACF Industries

Valves, Plug.....Jacketed plug valves can be supplied for air or hydraulic operation. Complete description, details & dimensions in new catalog supplement 356-S.
L329 *Parks-Cramer Co.

Valves, Solenoid.....Complete information on all models available. Also a 16-page brochure which lists over 500 corrosive media... coded for correct valve selection.
TL357 *Valcor Engineering Corp.

Valves, Stainless Steel.....New catalog covers valves in the patterns you want, in a choice of alloys that satisfy the requirements of practically all corrosive services.
155 *Jenkins Bros.

Process Equipment

Blenders.....Constructed of carbon steel, stainless steel or Monel metal, these blenders are engineered to fit each customers needs. Bulletin 080B is offered.
L286 *Sturtevant Mill Co.

Centrifugals.....The Roberts LS/SC provides a combination of features. No metal to metal moving parts, rigid feed, wash, effluent, and solids-discharge connections.
R329 *The Western States Machine Co.

Centrifuge.....Nozzle-Matic centrifuge, feeds with up to 5% solids and flow rates to 18,000 gallons per hour. Technical literature is available on request.
120-121a *DeLaval Separator Co.

Centrifuge, Horizontal.....Slurries up to 50% solids are processed by an ingenious horizontal centrifuge that applies 2,000 Gs of force. Technical literature.
120-121c *DeLaval Separator Co.

Centrifuge, Self-Opening.....The PX self-opening centrifuge easily handles a great range of solids. Automatic discharge controls can be provided. Technical literature.
120-121b *DeLaval Separator Co.

De-Sludger.....Process engineers involved in continuous clarification and separation will be interested in a booklet that gives operating principles of an automatic de-sludger.
334A Centrico, Inc.

* From advertisement, this issue

CUT *PROCESSING* COSTS

Automatic Thayer Scale Controls 3 Ingredients in Cranberry Sauce Processing, Cuts Handling Costs and Increases Profits.

Costly, time consuming measuring, feeding and blending operations in the making of cranberry sauce have been mechanized with 1 Thayer Scale. Now a Thayer Metering Scale continuously feeds cranberries, at precise rates, to the cooking process. In addition, the scale automatically controls the 2 other ingredients required, resulting in better product quality and uniformity at lower handling costs.

Unlike conventional scales, the Thayer Scale has no knife edge pivots to wear and cause inaccurate weighing. The Flexure-Plate suspension system of the Thayer Scale cannot wear, requires no maintenance, and accuracy is guaranteed for millions of weighings.

Thayer engineers will inspect your product and production process and demonstrate how your costs can be reduced by more accurate weight control.

Write for information on BAGGING, BATCHING, METERING and CHECKWEIGHING SCALES.

THE Thayer SCALE

THAYER SCALE CORP.

3 Thayer Park
Pembroke, Massachusetts
TAylor 6-2371
A Subsidiary of Sundstrand Corporation

2 grades of KENNAMETAL* provide answers to difficult corrosion-wear applications

These grades of Kennametal hard carbide alloys offer varying combinations of properties—to meet a broader range of corrosion-wear applications throughout industry.

Grade K601 provides an exceptionally high corrosion-wear resistance factor, as indicated in the accompanying table, for use under the most severe corrosion-wear conditions. It has a transverse rupture strength of 100,000 psi.

K701 is recommended for applications where corrosion is less severe or impact is greater. It has the essential properties to resist these conditions — and it offers a price advantage over K601. Transverse rupture strength is 150,000 psi.

Successful applications include needle valves, cones, sealing rings, balls and seats, sleeve inserts, spray nozzles, catalyst compacting dies, and coal processing wear parts—plus homogenizing wear parts used in food, paint, tobacco and other industries—and for valving, sealing and spraying slurries in refining petrochemicals, clay, soap, detergents and other bulk chemical processes.

If you have corrosion and wear problems with component parts, we will gladly help you select the Kennametal grade that offers the best and most economical application. For booklet "Proven Uses of Kennametal," which includes many applications in the chemical industry, write to KENNAMETAL INC., Dept. CE, Latrobe, Pennsylvania.

COMPARATIVE CORROSION AND WEAR RESISTANCE – KENNAMETAL AND SOME METALS

Material	Loss in mg/dm²/day 22° centigrade			Wear Resistance Factor	Combined Corrosion-Wear Resistance Factor
	50% NaOH	5% H_2SO_4	37% HCl		
K601 Kennametal	0.8	0.6	0.2	1112	55,500
K701 Kennametal	0.8	116	67	833	12
WC with 6% Cobalt	nil	123	163	203	7
Nickel	nil	39	3041	16	0.05
Ni-Cu Alloy	nil	40	2648	12	0.04
Co-Cr-W Cast Alloys	0.3	0.5	285	32	1

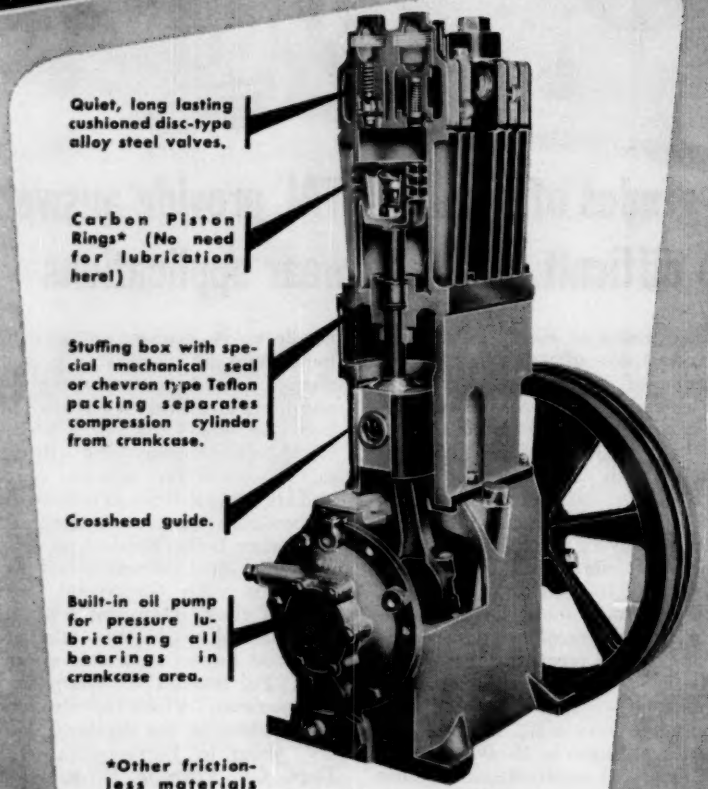
*Trademark

34229

INDUSTRY AND KENNAMETAL
...Partners in Progress

NO OIL CONTAMINATION WITH CORKEN "DRY CYLINDER" COMPRESSORS

Your product is protected by complete separation of cylinder and crankcase!


Quiet, long lasting cushioned disc-type alloy steel valves.
Carbon Piston Rings* (No need for lubrication here!)
Stuffing box with special mechanical seal or chevron type Teflon packing separates compression cylinder from crankcase.
Crosshead guide.
Built-in oil pump for pressure lubricating all bearings in crankcase area.

*Other frictionless materials available.

WRITE FOR BULLETINS VE-100 AND VE-102

Available as single-or two-stage machines—

(Single Stage Duplex)	(Two Stage)
Displacement 4—37 CFM	2—23 CFM

Max. Discharge Press. 265 PSIG—500 PSIG Intermittent

CORKEN'S INCORPORATED

PHONE CE 5-5517
P. O. BOX 1062
OKLAHOMA CITY, OKLA.

LITERATURE . . .

Drying System.....This 3'-6" diameter x 24'-0" long rotary flash dryer uses natural gas as the heat medium. Catalog "A" is available for details.
B354 *Davenport Machine & Fdry. Co.

Fabric Filter.....An extremely varied group of filter sizes, shapes & types is available. Specific information is offered along with an air pollution analysis kit.
L302 *John Wood Company

Filtering Unit.....G-140 series will remove all impurities from 25 microns on up. This unit never needs to be replaced. Full specifications available.
80 *Purolator Products, Inc.

Floats.....Industrial floats feature corrosion resistance, extreme strength, buoyancy and dependability. A complete bulletin is available on styles, sizes, etc.
BL339 *Chicago Float Works

Fluidometer Systems.....Multi-valve fluidometer systems economically & accurately batch anything that can be handled by a meter. Details in Bulletin F1-56.
T354a *Hetherington & Berner

Gyratory Screen.....features stacked-deck design to conserve valuable space. Cuts maintenance and downtime with all-stainless steel construction. Details.
48-49a *Allis-Chalmers

Homogeinzers.....along with equipment for heating, cooling, flavorizing, storing, separating, freezing, mixing, packaging and conveying are described in catalog.
78 *Cherry-Burrell Corp.

Jar Rolling Machines.....are available to handle single or parallel rows of jars, in double or triple tiers for processing as many jars as required. Catalog 79.
R355 *Abbe Engineering Co.

Laboratory Homogenizer.....Minimum sample one pint; capacity 15 GPH; pressures up to 8000 PSI. Additional information is contained in Bulletin LH-55.
R280a *Manton Gaulin Mfg. Co., Inc.

Lectrodryer.....The standard Type BZ operates between 40 to 150 psig. Special units are available for 300 psig & higher pressure. Details in Bul. BZ-161.
316 *Pittsburgh Lectrodryer Corp.

Liquid Filters.....Fine mesh liquid filters stop downtime, damaged equipment, contaminated products, customer & management complaint. Non-short circuiting design.
TL 355 *Ronningen Peter Co.

Magnetic Ferrous Traps.....protect against fine iron and tramp iron contamination to help assure product purity. Clean, simple design, no moving parts.
336A *Eriez Mfg. Co.

Mill.....The two-stage design of the RE Colloid Mill provides continuous micrometer control for producing superior emulsions or dispersions. Bul. C-57.
R280b *Manton Gaulin Mfg. Co., Inc.

Mills, Colloid.....for dispersing, emulsifying, disintergrating and homogenizing. Used where fineness and uniformity of grind are needed. Information is available.
T305 *Premier Mill Corp.

* From advertisement, this issue

Mixers.....Day Mixing Equipment is specifically designed for safe, fast, and efficient operation. Complete line for every mixing need. Further details available.
279 *The J. H. Day Co.

Mixers.....Lightnin Mixer features Lightnin Rotary Mechanical Seal which is an integral cartridge unit. Further information available.

Mixers.....Dependable mixing is assured to give you more profit in your process. Used for agitating, mixing, reacting, suspending solids & other applications. Bul. 581.
168 *Nettco Corp.

Molecular Vacuum Stills.....Operating costs of high vacuum stills are less than 1/10¢ per pound because of lowered heat input, higher yield. Bulletin 3-1.
306 *Consolidated Vacuum Corp.

Mulling.....Simpson Mix-Muller is specifically designed to put you in control of mixed properties. The Handbook on Mulling is available on request.
183 *National Engineering Co.

Pellet Mill.....to cut processing costs with skilfully engineered single units or complete systems. Bulletins, technical assistance & laboratory evaluation available.
338 *Sprout, Waldron & Co., Inc.

Process Equipment.....Votator process equipment and systems step up quality and profits. The whole story is contained in Bulletin V250-F-12 which is available.
170 *Girdler Process Equip. Div.

Process Equipment.....Glascote efficient, economical, reliable glass-lined processing equipment is described in Bulletin 105 which is available.
42-43 *Glascote Products, Inc.

Process Equipment.....Bulletin 443 is available on request for detailed information on the full line of equipment such as conveyors dryers, spray dryers, etc.
147 *Proctor & Schwartz, Inc.

Process Equipment.....The Super-D-Canter provides broad range solids & liquids processing at atmospheric or pressure levels. Further information is offered.
175 *The Sharples Corp.

Processor.....Holo-Flite processors handle more work, more efficiently. Heats to 500 deg. F., cooling range 1800 deg. F. to 0 deg. F. Literature is offered.
T301 *Western Precipitation

Pulverizers.....Mikro-Pulverizer offers fine or ultra-fine grinding, precise particle size control & economy of power and maintenance. Bulletin 51A is available.
165 *Mikro-Products Pulv. Mach. Co.

Purifiers.....Hi-eF Purifiers have patented two-stage principle of separation with no moving parts. Special Manual 803 contains data on 13 types of separators.
B352 *The V. D. Anderson Company

RDC Column.....combines many advantages such as high volumetric efficiency, high throughout capacity, elimination of interstage settling, etc. Bul. #T-1159.
154 *Gen. American Transportation

* From advertisement, this issue

Molasses Dairy Feeds Clog Scale Openings

Stainless steel interiors of automatic feed weighing scales have long provided good service for users of Richardson Scales for weighing molasses content feeds. But as molasses content increased, so did the time and effort required for cleaning.

Usually twice-a-day cleaning sufficed. But the higher the molasses content, the faster the feed adhered and built up on all platework. Downtime for cleaning went even higher.

Now Richardson Scale Company uses R/M "Teflon" sheets wherever molasses feed makes contact with the scales. Field experience proves that now scales never clog, cleaning requires only a moist sponge instead of a metal scraper and only 1/10 as much time as before.

R/M Bondable "Teflon"* Cuts Cleaning Time 90%

Do you have an application which can utilize the non-adhesive property and low coefficient of friction of "Teflon"? Talk to R/M—headquarters for "Teflon" rods, sheets, tapes, hose, machined parts, with or without bondable surfaces. Write for information or call your nearest R/M district office.

*Registered TM for Du Pont fluorocarbon resins

R/M

PLASTIC PRODUCTS DIVISION
RAYBESTOS-MANHATTAN, INC.
Manheim, Pa.

BIRMINGHAM 1 • CHICAGO 31 • CLEVELAND 16 • DALLAS 26 • DENVER 16 • DETROIT 2
HOUSTON 1 • LOS ANGELES 58 • MINNEAPOLIS 16 • NEW ORLEANS 17 • PASSAIC • PHILADELPHIA 3
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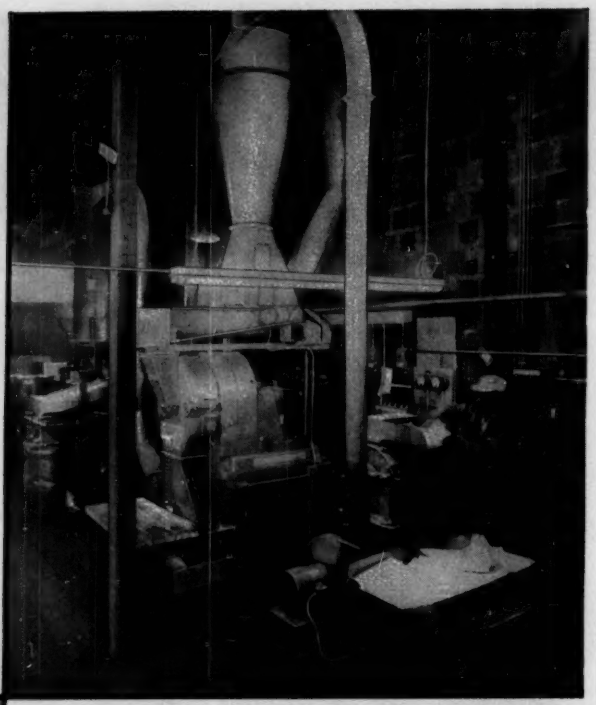

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Eliminating two major problems in processing polyethylene film scrap has been accomplished with a compact, relatively inexpensive, integrated system which produces agglomerates suitable for use by compounders or molders.

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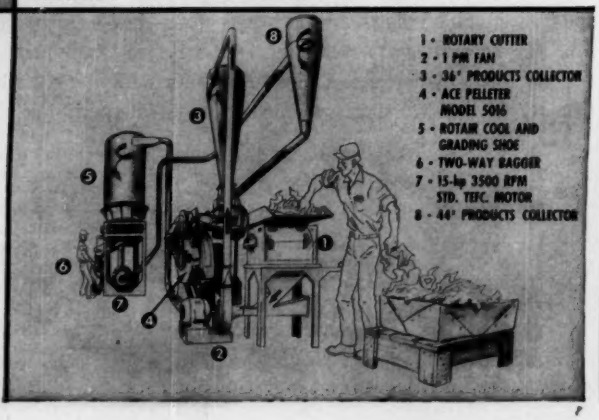
1 - ROTARY CUTTER
2 - 1 PIR FAN
3 - 36' PRODUCTS COLLECTOR
4 - ACE PELLETER MODEL 5016
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6 - TWO-WAY BAGGER
7 - 15-hp 3500 RPM STD. TEFC. MOTOR
8 - 44' PRODUCTS COLLECTOR

a compact, integrated system for producing agglomerates suitable for use by compounders or molders

607

LITERATURE . . .

Metering Pump.....Pulsafeeder metering pump offers precision metering at flow rates of from a few drops to 15.7 gal. per minute. Complete details in Catalog 59.
292 *Lapp Insulator Co.

Pump.....Moyno pumps for abrasives, corrosives or suspended solids. Available in nine sizes with capacities for 1/100 to 500 gpm. Bulletin 100-CE is offered.
163 *Robbins & Myers, Inc.

Rupture Disks.....Impervious graphite rupture disks are truly reliable. Maintain constant burst characteristics at all temperatures. Details in Bulletin 315-2.
57 *Falls Industries, Inc.

Scrubber.....New Impinjet scrubber features high efficiency and low operating costs. Liquid consumption is only 1 to 3 gals. per 1000 CFM at 20-40 psig. Catalog.
314 *The W. W. Sly Mfg. Co.

Scrubbers.....S-F Venturi scrubbers for air pollution control and for solids recovery from kiln gases. Has no nozzles, trays or jets to plug. Information.
51 *Chemical Construction Corp.

Separator.....Crystals, powders, pellets or lumps are kept hopping as they pass through the screens of the Syncro-Matic separator. Technical literature is available.
120-121d *DeLaval Separator Co.

Solids-Processor.....adds vacuum drying to liquid-solids blending. Systems completely packaged. In standardized models with charge capacities from 1 to 50 cu. ft.
86-87 *Patterson Kelly

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L333 *Groen Mfg. Co.

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30-31 *F. J. Stokes Corp.

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Centrifugal Pump.....2-page bulletin 1051-1 lists design features, performance curves and other specifications for model CF seal-less centrifugal pumps.
338A Chempump Div.

Compressor....."Compressor Evaluation Guide" points out the six key areas of judgment required for compressor evaluation and details them in full.
Cover *Worthington Corporation

Compresor, Piston.....Non-lubricated ringless piston compressor assures absolute contamination-free compresion of dry or moist gases. Information, specifications.
B356 *Sulzer Bros. Inc.

Compressors....."Dry Cylinder" compressors protect your product by complete separation of cylinder and crankcase. Information in Bulletins VE-100 & VE-102.
336 *Corken's Inc.

* From advertisement, this issue

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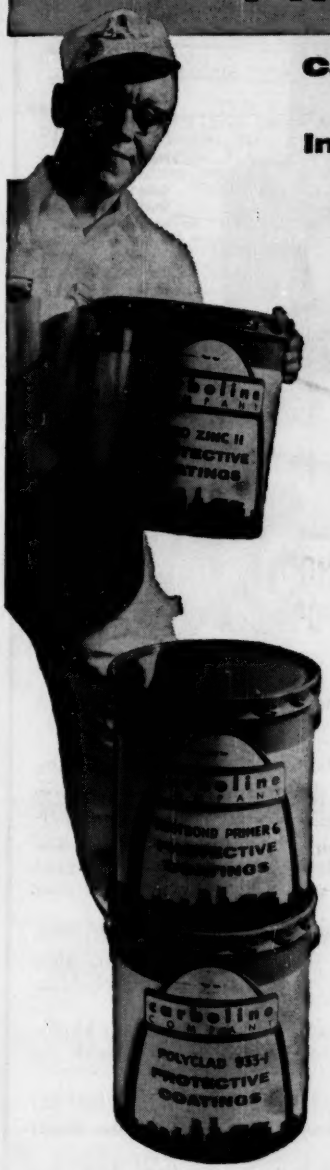

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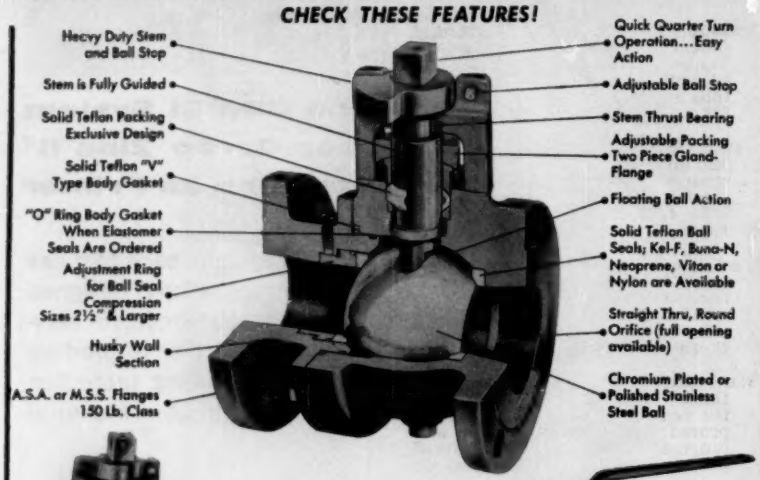
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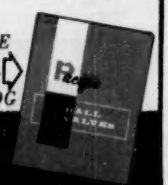

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LITERATURE . . .

Compressors, Pumps, Motors.....Catalog describes line of rotary air motors, air compressors and vacuum pumps for O.E.M. or plant use. Both oilless and lubricated models.
338B Gast Manufacturing Corp.

Diaphragm Compressors.....Bulletin 4071-C describing Corblin diaphragm-type compressors and pumps for all types of gases including highly toxic, corrosive gases is available.
152 *American Instrument Co.

Pumps.....for hard-to-handle liquids in the chemical industry. Pumps range from 25 to 2500 hp., pressures to 50,000 psi. Additional information is available.
146 *Aldrich Pump Company

Pumps.....Parts are standardized and readily interchangeable. Plant expansion is economical because of their adaptability. Complete descriptive lit. available.
149 *The Deming Co.

Pumps.....Eco Minilab Pumps are suitable for pumping a broad range of clear, non-abrasive media, including most severe corrosives. New catalog page HCT-161.
251 *Eco Engineering Company

Pumps.....Model 3195 pumps simplify process engineering and cut parts inventories. They offer maximum interchangeability. Bulletin.
24-25 *Gould Pumps, Inc.

Pumps.....DMR pumps interchangeability feature allows tailor made construction from standard parts to fit your needs. Information is contained in Bulletin B-1610.
158 *Peerless Pumps

Pumps.....available in iron, bronze, stainless steel, Ni-Resist, steel, ductile iron and other alloys. Available in 22 sizes. Additional information in Catalog 61SC.
331 *Viking Pumps Co.

Pumps.....For handling liquids, for heating, cooling and processing, a complete line of pumps is available. Feature simple design & rugged construction.
310 *The Weinman Pump Mfg. Co.

Pumps, Acid.....with rugged, simple frame construction & packingless design. Long wear parts, few in number, are available in a variety of metal alloys as well as plastic.
359 *A. R. Wilfiy & Sons, Inc.

Pumps, Metering.....for biological, industrial or sanitary use feature fixed or variable capacities and extremely compact design. Complete details & prices offered.
BL355 *Mechanical Products Corp.

Pumps, Proportioning..... Series 300 proportioning pumps are adjustable in operation from zero to full capacity. Full details are available on request.
R333 *American Meter Co.

Pumps, Submersible.....deliver water economically, consistently, silently and efficiently. Additional information is contained in Bulletin 203 which is available.
141 *Layne & Bowler, Inc.

Vacuum Boosters.....for high-vacuum with high throughput in a new or existing system. Forty-five sizes are available. Further information on request.
67 *Roots Connersville Blower

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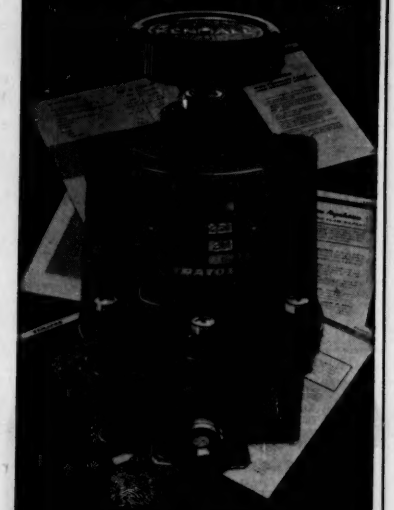
KENDALL/GOVERNAIRE



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LITERATURE . . .

Services & Micellaneous

Cleaning Program.....An Engineered Cleaning Program is comprehensive. Tankers cleaned in under 4 hours without sending a man inside. Details are offered.
332 *Oakite Products Inc.

Coating System.....This 3-coat system gives 2 to 3 times longer maintenance protection. Each coat has special properties. Illustrated Bulletin 400 gives details.
R339 *Carboline Company

Compacting Process.....recovers virtually 100% of waste fines. It compacts & screens your waste material into flakes. Further details are offered.
48-49e *Allis-Chalmers

Conservation Vents.....designed with flame arrester structure outside the vent housing. UL and FM approved and are made in a wide range of sizes. "Blue Book" offered.
334 *The Protectoseal Co.

Electronic Air Cleaners.....Precipitron air cleaners trap all dirt sizes including the damaging minute particles. The Precipitron brochure is offered.
109 *Sturtevant Div., Westinghouse

Engineering-Management Status..... The latest in profession advancement series, Engineering-Management Status: Dream of Mirage, Booklet E-9 is available.
L280 *Western Supply Co.

Fire Fighting Products.....Double strength foam is inexpensive & completely effective. Puts out fires fast, reduces storage costs & shipping costs. Information.
126 *Rockwood Sprinkler Co.

Laboratory Furniture.....A new 40-page catalog provides a quick reference for implement for basic planning of laboratory & hosital installations. Available on request.
358 *S. Blackman, Inc.

Lubrication System.....Alemite barrel-to-bearing lubrication is a product and profit boosting production tool. The Alemite catalog is available.
115 *Stewart-Warner Corp.

Midget Tools.....for speed assembly of tiny components. Sets assembled to order. A new industrial catalog has been prepared and is available on request.
322 *Snap-On Tools

TV Camera.....This new low cost, self-contained TV camera provides 650 line resolution. Application help is available along with Catalog 6-203 for details.
32 *Kin-Tol Div., Cohu Electronics

Technical Service.....Available to help customers solve production, application and development problems on wide range of products.
99 *Enjay Chemical Company

Water Softener.....Zeolite water softener means a simple switch to sodium ions from the usual hardness present in water supplies. Further details are available.
48-49c *Allis-Chalmers

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- 2—12,000 gal. NICKEL Clad Tanks.
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- 1—1,000 gal. NICKEL Clad Tank.
- 2—Oliver 5'3"x4' NICKEL Clad Rotary Vacuum Salt Type Filters.
- 3—Dorr 80' dia. Thickeners with agitator and drive.
- 4—Dorr 40' dia. Thickeners with agitator and drive.
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- 2—Chicago Pneumatic 26" x 14" Vacuum Pumps with 150 HP motors.
- 4—Feinc 8' x 12' Rotary Vacuum Steel Filters, string discharge.
- 1—5½' x 4½' x 50' Rotary Dryer.
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- 1—Buflovak 32" x 90" Double Drum Dryer.
- 1—Sperry 30" C.I. Filter Press, 27 chambers.
- 2—Pfaudler 300 gal. Glass Lined Jacketed Agitated Reactors.
- 5—NICKEL Centrifugal Pumps, 2", 3".

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- 1—Raymond #73612 Super High Side 6-Roll Mill, complete, 40 ton per hr.
- 4—Fuller Lehigh Mills, 48" and 57" dia., M.D.
- 2—6'6" dia. x 60' Rotary Dryers
- 1—Link-Belt 24" x 90' Troughing Belt Conveyor.
- 1—Bucket Elevator, 75' high.
- 3—Fuller Kinyon Pumps.
- 2—Stainless Steel Gas Scrubbers, 6' x 12', 7' x 14' with fans. Scales, Bins, Piping, etc.

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- 2—Sharples C-20 and C-27 Super-D-Hydrator, 316 S.S.
- 1—Bird 18" x 28", Solid Bowl, Continuous, 304 S.S.
- 2—Bird 24" x 38" Solid Bowl Continuous 304 S.S.
- 1—Bird 40" x 60" Solid Bowl Continuous, 316 S.S., unused.
- 3—Sharples PY14, PN14 Super-D-Canters 316 S.S.
- 2—Sharples #16, 304 S.S., 3 HP motor.

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- 1—Pfaudler 125 gal. 304 S.S. Jacketed Agitated Reactor, 150# int., 125# jacket.
- 3—Pfaudler 200 gal. glass lined jacketed Kettles.
- 2—Pfaudler 850 and 650 gal. Steel Jacketed, Agitated Reactors.
- 1—650 gal. 304 S.S. Reactor with 100 sq. ft. Bayonet Heater.
- 1—550 sq. ft. Buflovak monel single effect Evaporator.
- 1—500 gal. S.S. Mixing Tank, nickel coils.
- 6—7500, 6000 and 2000 gal. Rubber Lined Tanks.
- 1—1500 gal. Stainless Pressure Tank, 5' x 10', 90#.
- 1—2000 gal. horiz. 304 S.S. Tank, 5' x 12'.
- 1—2500 gal. vertical 304 S.S. Tank, 8' x 7'.
- 1—10,000 gal. rubber lined Tank 10' x 17'6".
- 2—2700 gal. 316 S.S. Vertical Agitated Tanks with Coils.
- 1—4200 gal. 316 S.S. Vertical Tank, 8' x 12'.
- 1—5500 gal. 316 S.S. Clad Pressure Tank, 250 psi.
- 1—12,000 gal. horiz. steel Pressure Tank, 7'6" x 36', 200 psi.
- 4—Stainless Heat Exchangers; 536, 370, 315, 250 sq. ft.
- 1—24" dia. x 35', 304 S.S. Bubble Cap Col.

FILTERS

- 1—#5 Sweetland Filter 304 S.S. 120 sq. ft.
- 1—Oliver 6' dia. Horizontal Filter, 316 S.S.
- 1—Oliver 4' dia. Monel Horizontal Filter.
- 1—Oliver 5' x 6' Steel Rotary Vacuum Precoat Filter.
- 1—U.S. 200 sq. ft. 304 S.S. Auto-Jet Filter.
- 1—Hercules 400 sq. ft. 304 S.S. Pressure Filter.
- 1—Oliver 5'3" x 8' Steel Rotary Vacuum, vaportite housing.
- 1—Feinc 3' x 1' 316 S.S. Rotary Vacuum Filter.
- 2—#12 Sweetland Filters, 36 leaves, 4" centers, 500 sq. ft.
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- 1—Buflovak Vacuum Shelf with 17—60" x 80" shelves.
- 2—Buflovak 42" x 120", atmospheric double drum Dryers, complete.
- 1—Buflovak 32" x 90" Atmos. Twin Drum.
- 2—Devine 4' x 9' single drum, atmospheric.
- 1—Buflovak 3' x 10' Rotary Vacuum Dryer.
- 1—Stokes 4' x 20', 304 S.S. Rotary Vacuum.
- 6—Louisville Rotary Steam Tube 5' x 25', 6' x 30', 6' x 50'.
- 2—Louisville 8' x 50' Stainless Steel lined Rotary Dryers.
- 9—Rotary Dryers 34" x 30', 4' x 40', 6' x 50', 6' x 60', 7' x 80', 8' x 87'.
- 1—Louisville 4½' x 25' Inconel Rotary.
- 2—Link Belt, 7'5" x 25', 6'4" x 24", S.S. Louvre Dryers.
- 1—Stokes model 38-A Tray Dryer with 16—36" x 36" S.S. Shelves.
- 2—Atmos. Tray Dryers, 16 shelves, 40" x 24".
- 2—10' and 4' dia. 304 S.S. Spray Dryers.
- 2—Wyssmont Dryers, 304 S.S. 6'2" and 9'6" dia.

MIXERS

- 1—Abbe 110 gal. 304 S.S. Jacketed Agitated Vacuum Dispersall Mixer.
- 2—Day Imperial 150 gal. jktd. double arm.
- 2—Baker Perkins 150 and 100 gal. jacketed double arm Sigma blades.
- 1—Baker Perkins 50 gal. jacketed, double-arm.
- 5—Day "Cincinnatus" double arm, 250 and 100 gal.
- 2—Steel jacketed Powder Mixers, 225 and 350 cu. ft.
- 1—Patterson 6' dia. Conical Blender 15 HP.
- 1—3' dia. Simpson Intensive Mixer.
- 1—2' dia. Simpson Intensive Mixer 304 S.S.
- 1—45' dia. Lancaster Mixer 7½ Hp motor.
- 1—Patterson Kelley 150 cu. ft. Twin Shell Blender.
- 1—Patterson 80 cu. ft. Conical Blender, 304 S.S.

MISCELLANEOUS

- 3—Kinney Vacuum Pumps, 1000 cfm, 10 microns, 15 HP.
- 2—Hardinge 5' x 22" steel lined conical Ball Mills.
- 3—Mikro Pulverizers, 1SH, 1SI and Bantam.
- 3—Abbe 2½" x 3' porcelain lined Pebble Mill XP motor.
- 1—Raymond 10" vert. Mill, 10 HP.
- 1—No. 1 Ball & Jewell Rotary Cutter.
- 1—#18 Cumberland Rotary Cutter.
- 3—Swenson Walker Continuous Crystallizers, 24" x 30' sections.
- 2—#842 Rotex Sifters, 60" x 84" double deck.
- 1—#24 Rotex Sifter, 20" x 64", Quadruple deck.
- 5—Day Roball Sifters, 40" x 120", 40" x 84", Double Deck.
- 3—Nash H6 Vacuum Pumps.
- 4—Stokes Rotary Tablet Machines DD2-DDS2-DS3-RB2.

Partial List of Values—Send for Complete Circular

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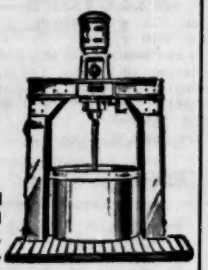
Hartig 4½" and 6" Electrically Htd Extruders; Vented; compl. with Drive. NRM 2½" Oil Heated Extruder with Varispeed Drive, Cumberland Pelletizer. Welding Engrs. 2" Twin S/S Screws; Oil Htd. Royle 2" Electr. Htd. with Crossheads. NRM 1½" Jktd. with Crosshead; Vari-Drive. Davis Standard 3¼" Wire Insulation Set-Up with Extruder, Crosshead, Capstan etc. Davis Standard 2" Wire Set up, as above. F-B Banbury Mixer Model #00 Complete 4 Stokes 150 Ton Self Contained Molding Presses complete; B. & J. Rotary Cutters, Lab. #1 and #2

SAVE $7,000 on FIRST'S FEATURED SPECIAL



48" Stainless Steel Bird Suspended Centrifuge Perf. Basket, Plow Discharge.

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FILTERS—FILTER PRESSES

4 Pressure Filters 30" x 56" Type 316 Stainless; 100 sq. ft.
Sparkler Steel Filter Model 33 S 17.
S/S Nutsche Type Filter; 6' x 2'.

MIXERS ALL TYPES

Baker Perkins Jktd. 5 gal. UNE-7, Dbl. Arm Mixer with pressure cover; 30 HP
Readco Jktd. 15 gal. Dbl. Arm Sigma Blade Mixer.
Baker Perkins Stainless Steel Lab Mixer; Sigma Arms; 6½" x 9½" x 11½".
Baker Perkins Jktd. Mixers, 50 gal., 150 gal., 200 and 300 gal.
NOW IN STOCK for IMMEDIATE DELIVERY. ALL SIZES FALCON Ribbon Blenders in Steel or Stainless.

REACTORS—PRESSURE VESSELS

2 Stainless 400 gal. Reactors Jktd. Agtd. by Patterson and Struthers.
6 Dorr-Oliver Stainless Steel Thickeners or Reaction Vessels; 550 gal. 5' x 5'.
Stainless Reactor, 2000 gal. Fully Jktd. Agitated.
Nickel Clad Reactor, 7' x 11'6".
Lancaster Stainless Lined Rotary Reactor or Digester; 50" x 17'4"; Jacketed; good for 300 PSI Internal.
Pfaudler Gl. Lined Reactors; all sizes from 50 to 500 gal.
Majonnier Stainless Vac. Pans; 3' x 10' and 6' x 12'; others.

MILLS—PULVERIZERS

2 Stainless Steel Micronizers 30".
Abbe, Ball & Jewell Rotary Cutters; in a wide range of sizes, capacities.
Ball Mills and Pebble Mills by Abbe, Paterson, International, some Jacketed; up to 8' x 8'.
Mikro Pulverizers up to No. 4's.
Fitzpatrick Comminutators; Models D, K and C; motorized.
American Ring Roll Crusher; 50 HP.
Mikro S/S Atomizers; Nos. 6 and 5.
Raymond Imp. Mills; many sizes.
Williams Hammer Mills to 60 HP.

CONTINUOUS FINE GRINDING EQUIPMENT

To be Sold Direct from Location

2 Allis Chalmers 7' x 22' (2 Compartment) Compeb Mills, Meehanite Liners; 400 HP
1 Allis Chalmers 9½ x 810 Preliminator or Continuous Ball Mill; Meehanite Liner magnetic-coupled to 400 HP Motor
3 Allis Chalmers 7' x 22' Continuous Ball Tube Mills, Meehanite Liners, each driven by a magnetic coupled 400 H.P. Motor now operating in closed circuit with
3 Raymond 14 Ft. Double Whizzer Mechanical Air Separators, each driven by 70 HP Motor. New in 1950

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CIRCLE F ON READER SERVICE CARD

LIQUIDATION

OMAHA, NEBRASKA

2—96" dia. x 22 plate steel beer-still columns, 44' high.
5—Buflovak 42" x 120" dbl. drum dryers, ASME 160#
2—Amer. 36" x 84" dbl. drum dryers
9—Davenport #1A #2A dewatering presses, vari-drives
2—French Oil type 2-S screw-type extraction presses 300 PSI, 60 HP.
5—Shriver 48" Cast Iron P. & F. filter presses, (50) chambers
2—19,900 sq. ft. quadruple effect calandria type evaporators
6—691 sq. ft. dbl. pipe coolers
3—American 654 sq. ft. spiral steel heat exchangers
18—Tubular heat exchangers, copper tubes: 1500, 1350, 1130, 637, 380, 290, 184, 176, 156 sq. ft.
2—9500 gal. horiz. cookers, 9' dia. x 20' long, ½" shell & heads.
2—Warren 12" x 12" cent. pumps
250—Steel cenrtifugal pumps, 1" to 12", 1 HP to 150 HP
2—Aldrich triplex pumps, 175# WP.
3—1000 KVA trans., 13800—460 v.

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OVER 5,000 MACHINES IN STOCK
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S.S. VACUUM DRYER

Stokes 3 ft. x 15 ft. strain. stl. Rotary Vacuum Dryer. ASME jacketed for 50 P.S.I. and S.S. steam shaft. With condenser, dust collector and drive. Excellent.

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IT COSTS LESS at M&E

2—16' MECHANICAL SEPARATORS
1—Raymond, all welded construction Single Whizzer
1—Sturtevant, welded construction, Whirlwind Centrifugal Separator
Both in excellent condition. Special price before being brought into our stock.

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CIRCLE K ON READER SERVICE CARD

CHEMICAL PLANT LIQUIDATIONS

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MODERN EQUIPMENT • ATTRACTIVE PRICES • IMMEDIATE REMOVAL

• STAINLESS COLUMNS •

78"x18'x¼" Vulcan 318 SS Bubblecap, 14 trays, 180 caps/tray, 50 PSI.
72"x30'x⅛" Budd 347SS Bubblecap, 21 trays, 38 caps/tray.
48"x41'x5/16" Vulcan 316SS Bubblecap, 40 trays 70 caps/tray 100 PSI.
36"x21'x¼" 316 ELC SS Packed, 15 PSI.
36"x20'x3/16" Vulcan 316SS Packed 100 PSI.
30"x23'x¼" 316 SS Packed 75 PSI.
14"x17'6"x⅛" 316 SS Packed
12"x18'8"x3/16" 347SS Packed 100 PSI.
18'x66'—7' cone bottom, ¼" 316SS Packed Absorber Column Stainless Packing

• COLUMNS •

72"x16'9"x⅜" Copper 8 Bubblecap trays
48"x25'x⅛" Copper 35 Bubblecap trays
42"x28'x⅜" Copper 40 Bubblecap trays
36"x11'6"x⅛" Copper 15 Bubblecap trays
20"x27' GLASS LINED 50 PSI full vacuum
18"x21' GLASS LINED Scrubber
16"x10' GLASS LINED 25 PSI full vacuum
84"x25'x⅜" Steel 8 Bubblecap trays
60"x68'x5/16" Steel 35 Bubblecap trays
36"x58'x5/16" Steel 35 trays with Reboilers
30"x61'x⅜" Steel 24 trays

• CENTRIFUGES—FILTERS •

Sharples C-27 Super-D-Hydrator Stainless
Sharples C-20 Super-D-Hydrator Stainless
40" Fletcher Susp Centrifuge Perf. 15/7½ HP
30" Susp Centrifuge—Imperforate Stainless
Sharples #6 Super Centrifuge Stainless Bowl
5'3"x3' Oliver Precoat Rot Vac Filter SS
4'x1' Bird Young Rot. Vac Filter Stainless
36"x24" Goslin Rot. Vac Filter Stainless
48"x36" Stainless Nutsche Filter
#11 Sweetland 640 Sq. ft. 48 Stainless leaves
18"x28" Bird Continuous Stainless

• DRYERS—KILNS •

8'8"x70' Ruggles Cole Dryer
8'x60'x⅜" Al. Chalmers Welded Kiln
7'x120'x9/16" Bethlehem Fdy. Kiln
7'x45'x½" Link Belt Welded Kiln
604-24 Roto-Louvre Dryer Stainless Steel
6'x124'x¾" Vulcan Kiln
502-16 Roto-Louvre Dryer
4'x40'x⅜" Welded Dryer NEW Shell
3'x16' Stainless Rotary Dryer

• REACTORS •

Pfaudler 500 gal ELL Gl. Lined Jktd. Agit.
Dopp 1700 gal Ni-Resist Jktd. Agit.
Dopp 1000 gal Ni-Resist Jktd. Agit.
Vulcan 1000 gal Everdur Coiled, Agit.
Patterson 1000 gal Steel Jacketed
Buflovak 900 gal Stainless Agit. Elec. Heat
Patterson 500 gal Steel Jktd. Agit. 2HP XP
Alloy Tank 750 gal Stainless Pressure Still
Alloy Tank 300 gal Stainless Pressure Still

• COMPRESSORS—VACUUM PUMPS •

Clark 9920 CFM 149PSIA Suct 239PSIA Dis
Al. Ch. Centrifugal 7500CFM @ 42.5PSI, 1250HP
Nash #9 Compressors 2150 CFM @ 16PSI
Worthington YO 1360 CFM @ 35 PSI; 150 HP
Worthington 1015 CFM @ 35 PSI Steam Driven
Norwalk Hydrogen Compressor 5 CFM15000PSI
Nash #4 Vacuum Pump 650 CFM @ 15"

• STAINLESS STEEL TANKS •

11000 gal 12'x15'x3/16" Agitated
11000 gal 8'x29'6"x3/16" dished 25 PSI
4500 gal 6'x25'x¼" dish/cone 25 PSI Coiled
4000 gal 8'x12'x3/16" dished Coiled
3500 gal 8'x9'x5/16" dished heads
1500 gal 6'x6'9"x¼" dished heads
1200 gal 5'x8'x¼" Agitated
750 gal 4'6"x6'x¼" dished 42 PSI
500 gal 4'x5'x5/16" dished heads
500 gal 4'x5'6"x¼" flat Agitated
(20) Tanks 50 to 400 gal some agitated

• TANKS •

12000 gal Aluminum 10'x23'3" dished heads
10000 gal Aluminum 9'x23'3" dished heads
7000 gal Aluminum 10'x14' dished heads
3500 gal Cooper 8'x9'x½" dished Coiled
2000 gal Copper 7'x7'x½" dish Agit Coil
500 gal Copper 4'x5'x5/16" dished Coiled
20000 gal Steel 12'x24'4"x⅞" dished 100 PSI
10000 gal Steel 8'x30' dished Coiled
10000 gal Steel 8'x30'x⅜" dished 60 PSI
6500 gal Steel 7'6"x20'x¼" dished
2500 gal Steel 5'x15'8" Heresite lined 68 PSI
2250 gal Steel 6'x19'x5/16" dished 114 PSI
1250 gal Steel 5'x8' dished Agit. Coil

• HAMMERMILLS—CRUSHERS •

Penna SX13 150TPH, 400HP Synchronous Drive
Dixie Mogul #5060 Manganese Lined
Raymond #50 Imp Mill Model C2-855
Bacon Hevi-Duty Style B 20"x8" Jaw Crushers
Universal 5"x8" Jaw Crusher Manganese Jaws
Sturtevant 8"x5" Double Roll Crusher

• SPECIAL ITEMS •

TRIPLEX PUMP—2¼x4 Stainless 2000PSI
BLOWER 2500 CFM 10 PSI Read Standardair
GAS PUMP 20"x20" Roots Connersville "RS"
GAS METER 8"x24" Roots 60000CFH
CRYSTALLIZER Squire 40"x30" Agit, Jktd.
CRYSTALLIZER Buflovak 6' Vacuum Jktd. Agit
CRYSTALLIZER Swenson 24"x20' Jktd. SS304
AIR DEHYDRATOR-Anders 8FA Automatic
ABSORPTIVE DRYER-Kemp FE02-S Dual Tower
WHIZZER Raymond 30" Double
SIFTER 30"x96" Roball STAINLESS Screen
SIFTER 40"x84" Roball Single Deck
SIFTER 60"x84" Rotex STAINLESS 1 Deck
SIFTER 48" Sweco-Triple Deck Model A9062
CONVERTER—St. Wells 10'x29' 10000 sq. ft.
FURNACE—St. Wells 1MM/BTU Oil fired
HEATER 150KW Hot Oil Hynes Elec. Co.
BRIQUETTE PRESS Komarek Greaves 27"x24"
MIXER 300 gal. B.P. STAINLESS Sigma 18DIM
BLENDER Conical 6' Paterson 69CF 10 HP
BLENDER Conical 12' Paterson 500CF SS clad
EVAPORATOR—435 Sq. ft. Single Effect
TUBE MILL Al.Ch. 7'x24' Mang. Lined 500 HP
BALL MILL Traylor 8'x11' Steel Lined 300 HP
CENTRIFUGAL PUMPS—STAINLESS—1" to 3" 10 to 750GPM 35 to 100' Head

• CONDENSERS—HEAT EXCHANGERS •

983 Sq.ft. All Copper ⅝"x18ga.x8' Tubes
760 Sq.ft. All Copper ¾"x14ga.x14' Tubes
246 Sq.ft. All Copper ¾"x16ga.x12' Tubes
6931 Sq.ft. Steel 2"x11ga.x12' Tubes
1056 Sq.ft. Steel ¾"x16ga.x10' Tubes
141 Sq.ft. Steel ¾"x14ga.x8' Tubes

• STAINLESS HEAT EXCHANGERS •

2320 Sq.ft. 33"x21'—1"x16ga.x16' Tubes
1000 Sq.ft. 27"x168" ¾"x16ga.x14' Tubes
890 Sq.ft. 22"x20'8" ⅝"x16ga.x14'Tubes
800 Sq.ft. 23"x17'10"—¾"x16ga.x16' Tubes
615 Sq.ft. 22"x15'9"—⅝"x16ga.x10' Tubes
420 Sq.ft. 18"x9'6"—¾"x18ga.x8' Tubes
300 Sq.ft. 14"x19'6"—¾"x18ga.x12' Tubes
235 Sq.ft. 16"x8'3"—⅝"x16ga.x7' Tubes
188 Sq.ft. 11"x16'8"—⅝"x14ga.x12' Tubes
146 Sq.ft. 11"x13'10"—⅝"x16ga.x9'6" Tubes
68 Sq.ft. 8"x17'3"—¾"x16ga.x16' Tubes

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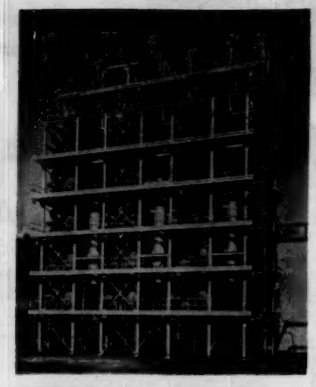


STAINLESS STEEL TANKS

6—13,300 gal., 12' x 15'9", cone top.
3—11,500 gal., 11'6" x 15'6", cone top.
18—3650 gal., 10' x 7', open top.
3—3000 gal., 5' x 19', T347SS, ASME 60 psi, dished heads.
60—1350 gal., 4' x 14', T347SS, ASME 60 psi, dished heads, int. coils.
9—1300 gal., 7' x 4'6", T321SS, closed
3—1100 gal., 4' x 11', T347SS, ASME 60 psi, 3/16" shell, ¼" heads.
27—476 gal., 4'6"x4', open top.
54—475 gal., 5'6"x2'6", open top.
27—445 gal., 6'x2', open top.
3—300 gal., 4'x3', T347SS, ASME 60 psi, dished heads.
9—285 gal., 41"x49", open top.
9—260 gal., 40"x48", closed top.

GLASS-LINED TANKS

18—Pfaudler 11,500 gal. horiz. blue glass-lined tanks, 8' x 30', ½" shell, 7/16" dished heads, 20 psi. With 75 sq. ft. nickel coil, Aurora St. St. sump pump.

STEEL PRESSURE TANKS

9—27,500 gal. 11' x 38', dished, ASME 75 psi.
11—27,500 gal. 11' x 38', lead-lined.
2—14,000 gal., 8' x 36', dished.
2—11,000 gal., 8' x 27', dished, ASME 300 psi.
5—9000 gal., 8' x 23', dished.
54—5200 gal., 6' x 24', dished, 60 psi.
3—3300 gal., 6' x 15-6", dished, ASME 125 psi.

ACID EQUIPMENT

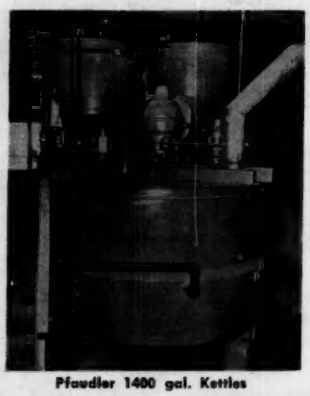
4—Cottrell carbon-tube electric-mist precipitators, (88)-tubes, lead-lined shell.
8—Graver concentrating drums, 10' dia. x 23' long, lead-lined, with furnaces.
8—5500 gal. gas-cooling tanks, lead-lined.
25—Acid-cooling tanks, lead-lined.
16—Duriron denitrating concentrators, 24" dia.x15' high, packed w/Amorphous Quartz.
4—Duriron 24" dia. x 4' high vac. denitrators.

FILTER-TANKS

54—Pfaudler 475 gal. St. St. filter tanks, 66" x 30", 24 sq. ft. filter plate.

KETTLES—REACTORS

72—1400 gal. Pfaudler blue glass-lined jacketed kettles, 84" dia. x 54" high, open top, Stainless Steel cover, 3 HP Agit., Adj. baffle.
18—1250 gal. Pfaudler blue glass-lined jkt. reactors (Sulphonators), 72" dia. x 72" high, closed, 3 HP Agit.
54—600 gal. Pfaudler Stainless Steel ammoniating & crystallizing jkt. kettles, 60" dia. x 46" high, open top, Fume hood.
72—250 gal. Pfaudler blue glass-lined jacketed kettles, 42" dia. x 36" high, open top, Stainless Steel cover.



Pfaudler 1400 gal. Kettles

COLUMNS—HEAT EXCHANGERS

16—24" dia. x 15' high Duriron packed columns.
1—24" dia. x 33' high Duriron & St. St. packed column.
4—24" dia. x 4' high Duriron vacuum denitrating columns.
6—1450 sq. ft. T347SS gas condensers, 3-pass Vert. units, inner & outer tubes.
3—1000 sq. ft. Duriron cascade-type pipe coolers.
3—564 sq. ft. Stainless Steel burner-Preheaters, gas condensers, 3-pass.
2—435 sq. ft. Amer. spiral steel exchangers.
9—400 sq. ft. Stainless Steel open-pipe coolers, 2⅜" OD pipe.
12—162 sq. ft. Amer. spiral Stainless exchangers.
48—Duriron pipe coolers, 159, 130, 125, 99, 54, 44, 42, 10 sq. ft.
3—18 sq. ft. Ammonia evaporators.

COMPRESSORS—BLOWERS

3—Worthington 3500 CFM air comp., 24 x 15, type LTC-4, 500 HP gas driven.
1—Chicago-Pneu. 3026 CFM air comp., size #19-32-30-18 x 24, horiz. steam driven.
8—Elliott turbo-blowers, 11,620 CFM, type 0, 15.9 psi discharge, 125 HP.
18—Ing.-Rand 6 x 6 x 5 air comp., V-type, 2 cyl, #67D9, type 30, 10 HP.
3—Frick 4 x 4 Ammonia comp., type HB.
2—Worthington 5½ x 3⅛ x 3½ air comp., V-type, 7½ HP.

CENTRIFUGAL PUMPS

20—Worthington 3" x 2", Worthite, #2CG2B, 75 GPM @ 139' 15 HP.
18—Worthington 2" x 1½", Worthite, #1½CG1A, 5 HP.
81—Worthington 2" x 1½", Worthite, #1½CG1A, 3 HP.
30—Worthington 2" x 1½", Worthite, #1½CG1.
27—LaBour 2" x 1½", T316SS, size #15, type DPI, self-priming, 3 HP.
3—Worthington 1½" x 1", Worthite.
8—Ing.-Rand 10" x 8", Iron, size #8AFV, 1800 GPM.
50—Misc. Iron cent. & gear pumps.

BOILERS

3—3000 CFM Edgemoor waste-heat boilers, 250 psi, 535 sq. ft., ASME.
5—435 HP Comb. Eng. water-tube boilers, 300 psi, 4620 sq. ft., 34,500 lb. steam/hr. @ 225% of rating, gas or oil fired.

MISCELLANEOUS

3—Alloy Fab. gas mixer-filters, (3) compartments, Stainless Steel contact parts.
30,000'—Stainless Steel pipe; 6", 4", 3", 2", 1½", etc.
10,000'—Stainless Steel vapor pipe; 12", 16", etc.
10,000—Valves, Stainless Steel, all sizes.
18—Screens, Stainless, 33"x53", single deck.
18—Toledo platform dial scales, 200#.

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CIRCLE M ON READER SERVICE CARD

PERRY FOR PROCESS EQUIPMENT

STAINLESS STEEL TANKS

1—3700 gal., T304, 6′ x 17′, int. coils.
1—3400 gal., T304, 6′ x 16′, dished.
1—3300 gal., T304, 6′ x 14′-6″, dished top, hemisph. bottom, 3/8″ const.
3—3000 gal., T347, 5′ x 19′, dished ASME 60 psi.
1—2700 gal., T304, 7′-6″ x 7′-6″, dished bottom, turbine Agit., 120 sq. ft. coil.
2—2600 gal., T316, 7′ x 8′, dished, coils.
1—2350 gal., T304, 5′ x 16′, coils.
3—2200 gal. T304, 8′ x 6′, sloping bottom.
1—2100 gal., T316, 7′ x 6′-3″, dished, open-water jkt., 5HP Agit.
3—2100 gal., T304, 8′ x 5′-6″, dished bottom, 52 sq. ft. coil, Agit.
1—2000 gal., T316, hopper, cone bottom.
1—2000 gal., T304, 78″ x 46″ x 14′-3″ oval.
1—2000 gal., T304, 8′ x 5′, dished, hinged top.
12—1750 gal., T304, hoppers, cone bottom.
60—1350 gal., T347, 4′ x 14′, dished, ASME 60 psi, coils.
1—1300 gal., T304, 6′ x 6′, dished, hinged.
3—1100 gal., T347, 4′ x 11′, dished, ASME 60 psi.
1—1000 gal., T304, 4′-6″ x 8′-6″, dished.
2—1000 gal., T304, 4′-6″ x 8′-6″, flat heads.
1—937 gal., T304, 6′ x 4′, open top.
1—750 gal., T304, 5′ x 5′, dished.
6—685 gal., T316, 3′ x 13′, coils.
1—600 gal., T304, 5′ x 4′, dished.
1—585 gal., T304L, 5′ x 4′, flat heads.
3—300 gal., T347, 4′ x 3′, dished, ASME 60 psi.

PRESSES

3—Komarek-Greaves 160,000 psi briquette presses.
4—Davenport dewatering presses; #1A, 2A, 3A.
1—French Oil #2-S extraction press.
2—Stokes #DDS-2 rotary tablet presses.
1—Stokes #T single-punch tab. press.
1—Stokes #RD-3 rotary tablet press.
1—HPM 63 ton steeping press, UNUSED.

KETTLES—REACTORS

1—1800 gal. T316SS reactor, vacuum internal, new jacket, Agit.
4—1350 gal. T347SS Kettles, open top, paddle agitators.
1—1000 gal. Dopp cast iron Kettle, 125# jacket, 15# int., Agit.
1—750 gal. Graver T304SS jkt. fermenter, ASME 30# int., 30# jkt., 10 HP Turbine Agit.
1—600 gal. Bartlett & Snow SS evap. & crystallizing jkt. Kettle.
21—600 gal. T304SS reactors, Jkt., Agit.
2—500 gal. T304SS reactors, jacketed, ASME, Vacuum—Unused.
6—465 gal. T304LSS reactors, jacketed, 150# int., 175# Jkt.
1—300 gal. Pfaudler blue G/L reactor, Agit., Jkt., ASME.
1—300 gal. Glascote blue G/L reactor.
1—200 gal., T304SS, vac. int., 200# WP Jkt., Agit.

MIXERS—MILLS

40—Baker-Perkins #17, 200 gal. sigma-blade, jkt. mixers.
1—Baker-Perkins #16-UUEM, 150 gal. Disp.-blade, jkt., 150 Hp, vaulted cover, motorized tilt.
1—Baker-Perkins #15, 100 gal. Disp., T347SS, 25 HP drive.
1—Baker-Perkins #15-UUMM, 100 gal., Disp. blade, ASME jkt., 100 HP, Comp. Cover, motorized tilt.
1—J. H. Day #6, 100 gal., St. St. sigma.
2—J. H. Day #5, 75 gal., sigma.
1—Raymond 66″, 6-roller mill, 200 HP.
1—Raymond 50″, 5-roller hi-side mill.
1—Allis-Chalmers 5′ x 5′ ball mill.
13—Abbe 6′ x 8′ batch pebble mills.
2—Hardinge 7′ x 36″ conical mills.
1—Babcock & Wilcox #E-32 mill, 75 HP.
1—Gemco 60 cu. ft. T304SS conical blender.
1—Mikro #2TH pulverizers, 10 HP.

EVAP.—STILLS

COLUMNS—CONDENSERS

7—4050 sq. ft. calandra type evap., copper tubes, cast iron shell.
1—Mojonnier 2085 sq. ft. triple-effect Stainless Sanitary evaporator.
4—Buflovak double-effect stainless evap. vert. long-tube type: 1025, 840, 710, 588 sq. ft.
1—Stokes 118 sq. ft. T316SS Still.
1—Barlett & Snow 6′ dia. Stainless jkt. evap.-crystallizing kettle.
1—Vulcan 110″ dia. x 16′ high T316SS bubble-cap column, 10 trays.
1—Vulcan 60″ dia. x 16′ high, T316SS bubble-cap column, 10 trays.
1—Vulcan 60″ dia. x 42′ high T316SS bubble-cap column, 35 trays.
1—36″ dia. x 9′-8″ T316SS bubble col.
15—Copper bubble-cap columns, 24″ to 54″ dia., to 51′ high.
1—1960 sq. ft. T316SS exchanger, remov. bundle, ASME 75# WP.
1—1450 sq. ft. T316SS condenser.
5—1400 sq. ft. T316SS gas converters.
3—800 sq. ft. T316SS condensers.
1—730 sq. ft. T316SS exchanger.
1—510 sq. ft. T316SS condenser.
30—T316SS condensers & exchangers: 427, 425, 410, 400, 290, 277, 264, 250, 200, 185, 165, 150, 145, 105, 83, 73, 54, 52, 50, 47, 30 sq. ft.
12—185 sq. ft. T304SS U-tube coolers.

FILTERS—CENTRIFUGALS

6—Shriver 48″ C.I. P&F filter presses, 1000 sq. ft., closed delivery.
6—Valley 36″ aluminum P&F filter presses, 65 ch., closed delivery.
5—Sweetland #12 filters, (72) stainless leaves, open deliv.
2—Sweetland #7 filters, 239 sq. ft.
1—Niagara #510-28, T316SS filter.
1—Oliver 5′3″x8′ recoat rotary vacuum filter, UNUSED.
2—Oliver 5′3″x3′ precoat rot. vac. filter, T316SS, ASME 30# WP.
1—48″ Tolhurst susp. cent., T304SS.
5—40″ A.T.&M. susp. cent., T304SS.
2—32″ A.T.&M. susp. cent., T304SS.
1—12″ A.T.&M. susp. cent., 1304SS.
26—Sharples #AS-16V super cent., Inconel, vapor-tite, sludge-disch. frame.
2—Sharples #16-P super cent., T304SS.
2—Sharples #C-20 Super-D-Hydrators.
1—Bird 18″ x 28″, T316SS, conical.
1—Bird 24″ x 38″ cylin. Steel.
2—Bird 24″ x 38″, T304SS, cylind.
3—Bird 24″ x 24″ Slotted, Monel

DRYERS—KILNS

5—Buflovak 42″ x 120″ double drum dryers, ASME 160# WP.
1—American 42″ x 120″ dbl. drum, ASME, St. St. Acc.
1—Buflovak 42″ x 90″ Dbl. drum.
1—Buflovak 32″ x 72″ twin drum dryer, chrome plated drums, St. St. trim.
2—American 36″ x 84″ Dbl. Drum.
1—Buflovak 32″ x 52″ dbl. drum.
1—American 36″ x 84″ double drum dryer, ASME, VACUUM.
1—Buflovak 5′ x 12′, single drum dryer, Vacuum UNUSED.
5—F. J. Stokes #138J-16, 195 sq. ft. vac. shelf dryers.
1—Buflovak 110 sq. ft. vac. shelf.
1—Turbulaire Stainless spray dryer.
1—Nerco-Niro stainless spray dryer.
1—Vulcan 10′ x 11′ x 175′ rotary kiln.
2—10′ x 78′ rot. dryers, 3/4″.
2—Hardinge 8′-8″ x 70″ rotary, 3/8″.
1—Traylor 8′ x 80′ rotary, 3/8″.
2—Davenport 8′ x 60′ rotary, 7/16″ welded burners, fans, etc.
2—8′ x 56′ rot. kilns, 1/2″ welded.
1—7′6″ x 62′ rotary kiln, 1/2″.
1—Louisville 4′-6″ x 25′ steam-tube.
1—Bartlett & Snow 3′ x 15′ rotary dryer, Everdur metal shell.

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3—Sweetland #12 Filters, 72 lvs on 2" centers. Hydr closing. Exc cond

1—Oliver 3' x 2' SS rotary vacuum Filter. Continuous. Comp equipped

3—Oliver 8' x 14' cont. vac. rotary Filter. Closed drums. With drive

1—Sperry 24" x 24" plt & frm Filter Press. Steam heated plts. 26 chamb.

1—St Regis "Bates" Bag Filler. 3 Valve Model 107 FC, 25 HP Ex prf

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Filter Presses: 8" to 36" Iron & Wood.
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686 CFM	100 PSI	14x13 Ing. ES	
805 CFM	125 CFM	17-10x12 CP ace	
1050 CFM	60 PSI	13-13x12 IR-XRE	
2200 CFM	100 PSI	26-15x18 Ch. Pn. ace 350-HP 3-6-4160-4600 .8 PF	
2520 CFM	125 PSI	17-10¾x8 Clark CMA-4L	
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Simpson 24" Lab. SS Mix Muller, 1½ HP motor
Gruendler #3 Hammermill, Whirlbeater, 22"
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SPECIALS

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Concentrator: Deister 5x8' rubber covered.
Column: 24" x 22', 316 stain. steel.
Pebble Mills: Abbe #3, #6, and others.
Dryer: American 24x48" dbl. drum.
Dryer: Bowen lab. spray, st. st.
Evaporator: Buflovak sgl. eff. st. st. 94 sq. ft.
Dryer: Porter 2 x 4' vac. drum., st. st.
Centrifugal: Tolhurst 25" rubber, 2-speed.
Filter: Sweetland #5 st. st. lined.
Filter: Eimco, drum 18" x 12".
Dryer: Stokes vac. shelf model 138-B-5
Dryer: Proctor & Schwartz 6-tray st. st.
Centrifugal: AT & M 60" st. st. perf.

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Evaporator: Buflovak dbl. eff. st.st. 606 sq. ft.
Evaporator: Mojonnier dbl. eff. st.st. 1250 sq. ft.
Evaporator: Buflovak sgl. eff. st.st. 67 sq. ft.
Evaporator: Swenson four eff. C.I. 5700 sq. ft.
Dryer: Double Drum, 42 x 120 American.
Dryers: Double Drum, 42 x 90; 32 x 100 Buflovak.
Dryer: Rotary Steam Tube, Louisville 6' x 25' (2).
Dryer: Lab. Spray st.st. Western Precip.
Centrifuges: Tolhurst 40" and 26" Suspended, perf.
Centrifuge: Bird continuous, 18 x 28, S.S. T316.
Filter, Rotary Vacuum with pressure housing, Dorr Oliver 5'3" dia. x 4' face (2).
Tanks: (2) 2300—1500 gal. Vertical St.St.
Tanks: (2) 3000—1500—900 gal. vertical St.St. for vacuum, with coils.
Kettles: (2) 500 gal. agitated st.st.; with 15 P.S.I. steel jacket.

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2—Wemco 2M-HMS Plants
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5' x 8' & 4½' x 9' KVS Air Swept Ball Tube Mills
Ball Mills: No. 56, 5' x 5', 6' x 4', 6' x 9' & 7' x 22'
Hardinge Mills: 3 x 8', 3' x 24" & 5' x 22"
Rod Mills: 4' x 11', 6' x 12' & 7' x 15'
Jaw Crushers: 8" x 10", 9" x 24", 10" x 30", 12" x 20", 13" x 24", 14" x 20", 18" x 36", 30" x 36", 48" x 60", 48" x 72", 66" x 84"
Crushers, Fine Reduction: 22", 2', 3', 4', 5½' & 7'
436 Allis Chal Hydrocone 75 H.P. Motor
Crushers, Roll: 24" x 14", 30" x 14", 48" x 18"
Rotary Dryers: 5' x 30', 5' x 35', 6' x 50', 6' x 70' & 8' x 80'
Rotary Kilns: 36"x30', 6'x70', 7'x120' & 9'x160'
2—42" x 120' Buflovak Atmos. Double Drum Dryer
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1—Pfaudler Model XL 1000 gal. glass lined jacketed reactor
2—International SS horiz. jacketed double ribbon blenders, 40 cu. ft., complete with motors.
1—AT&M SS 40" link suspended centrifuge with perforate basket and explosion proof motor.

AUTO. KETTLES, REACTORS

2—Pfaudler Series EM 300 gal. glass lined jacketed reactors
1—Pfaudler 750 gal. glass lined reactor, jacketed
4—Pfaudler Series P glass lined jacketed reactors, complete with agitators and drives, 5, 20 and 30 gal.
2—Theo. Walters, Hastelloy B, 300 gal. jacketed reactors
2—Blaw Knox 200 gal. jacketed autoclaves, nickel, 175 psi jacket and internal
1—Blaw Knox 300 gal. stainless steel vacuum reactor
2—Blaw Knox steel autoclaves, 600 gals.
1—Alloy Fabricators steel jacketed autoclave, 600 gals.
1—Van Aist 300 gal. stainless steel jacketed kettle
2—Process Equipment 10,000 gal. SS vertical tanks, NEW
1—10,000 gal. horizontal rubber lined storage tank
3—Glascote 500 gal. glass lined vacuum receivers

DRYERS

2—Bonnot rotary kilns, 8' x 115', complete
1—Bonnot rotary cooler, 8' x 50', complete
1—Allis Chalmers stainless steel rotary dryer, 6' x 50'
10—Allis Chalmers rotary dryers, 6' x 50' and 7' x 60'
1—Buflovak SS jacketed rotary vacuum dryer, 5' x 30'
1—Link Belt steel roto louver dryer, Model 207-10
1—Link Belt steel roto louver dryer, Model 502-20
2—Stokes SS jacketed rotary vacuum dryers, 3' x 15' and 2' x 6'
1—American 42" x 120" double drum dryer, ASME, complete
1—Buflovak steel jacketed rotary dryer, 3' x 15'
2—Stainless steel pilot plant spray dryers
1—Stokes single door vacuum shelf dryers, 6 shelves

CENTRIFUGES

1—AT&M 48" SS suspended type centrifuge, complete
1—Fletcher 48" SS underdriven centrifuge, complete
1—AT&M 26" type 316 SS suspended type centrifuge, complete
5—Tolhurst 40" and 30" rubber covered centrifuges
1—Sharples type 316 SS Super-D-Canter, PN-14, complete
1—Sharples type 316 SS centrifuge, Model D-2
1—Sharples C-20 Super-D-Hydrator, monel

FILTERS

2—Oliver SS rotary filters, 3' x 2' and 3' x 4'
1—Hercules SS filter with 6 leaves

THE GELB GIRL—JUNE 1961

12—Sweetland #12 pressure leaf filters with 72 SS leaves
1—Niagara stainless steel filter, Model 510-28
1—Sperry 36" x 36" heresite covered filter press, 40 chambers
10—Shriver plate and frame filter presses, 12" to 42"

MIXERS

1—Gemco type 316 SS jacketed conical rotary vacuum blender, 92 cu. ft.
1—Sturtevant #7 Dustite rotary batch blender, NEW
15—Robinson type 304 SS horizontal blenders, 255 cu. ft.
1—Robinson type 304 SS horizontal blender, 125 cu. ft.
1—Baker Perkins 150 gal. dispersion mixer, complete
1—J. H. Day 5 gal. double arm sigma blade mixer, SS
1—Stokes stainless steel granulating mixer, Model 21-J

MISCELLANEOUS

1—Cleaver Brooks 500 HP package steam generator, 200#
1—Cleaver Brooks 150 HP package steam generator, 150 psi
1—Superior 300 HP package steam generator, 125 psi
1—Sprout Waldron pelletizer, Type 501 FF
1—Williams "Comet" 4 roll mill, complete
1—Raymond 2 roll high side mill
1—6" x 14" Ross 3 roll paint mill, high speed, complete
1—Vulcan SS bubble cap column, 4' dia. x 25 plates
1—Griscom Russell SS heat exchanger, 900 sq. ft.
1—Downington SS heat exchanger, 750 sq. ft.
3—Badger SS heat exchangers, 500 sq. ft. and 600 sq. ft.
4—Patterson SS condensers, 200 and 300 sq. ft.
20—Davis Engineering SS heat exchangers, 102, 119, 136, 166 sq. ft., NEW
2—Davis Engineering Carpenter 20 heat exchangers, 120 sq. ft.
2—Mikro Bantam pulverizers
2—Mikro #3TH SS pulverizers, complete
3—Pfaudler glass lined thimble type condensers, 9 and 14 sq. ft.
1—Struthers Wells SS 1150 sq. ft. single effect evaporator

1—300 gal. Hastelloy "B" jacketed pressure reactor
4—Patterson Kelley SS twin shell blenders, 4 qt. and 2 cu. ft.
1—125 gal. SS jacketed autoclave with impeller type agitator and drive, 125 psi jacket, 75 psi internal
1—Banbury #1 mixer with 30 HP motor.

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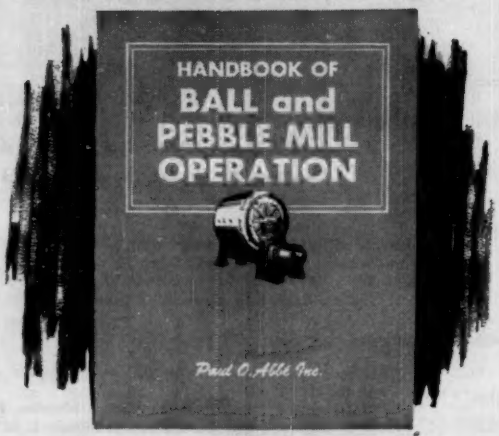

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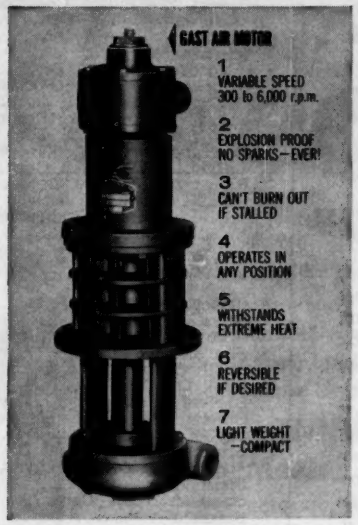
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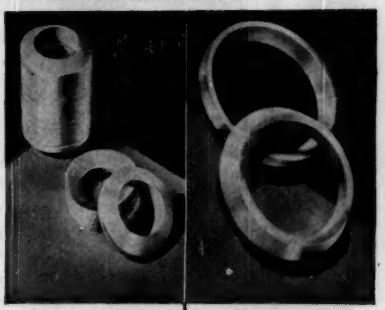

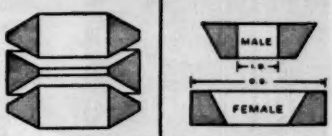

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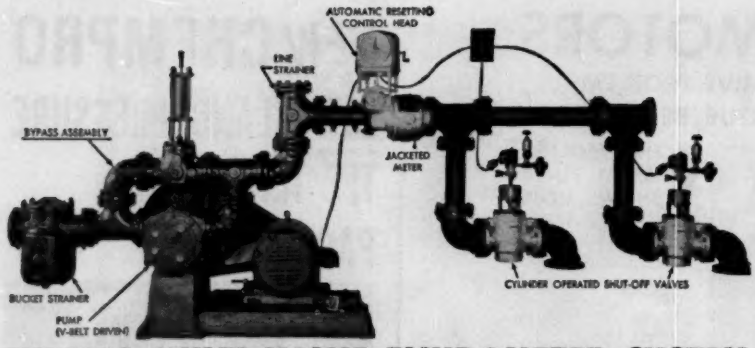

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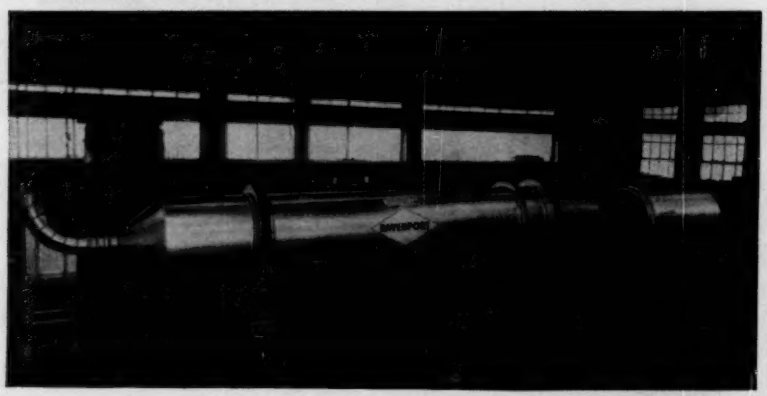

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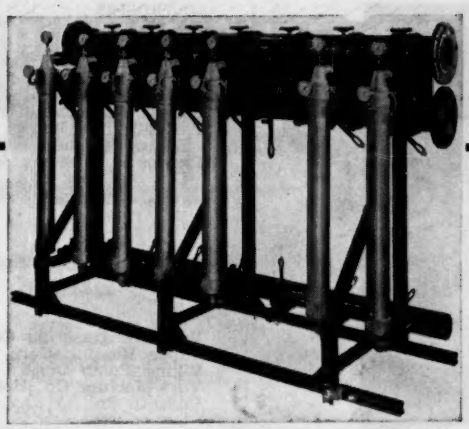

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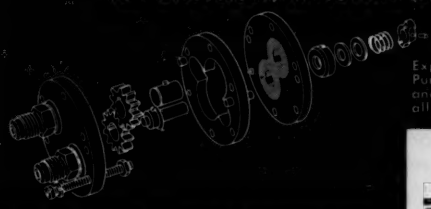

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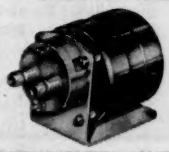

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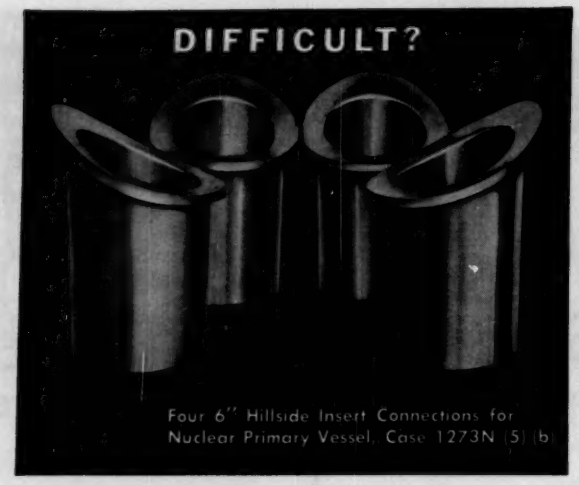

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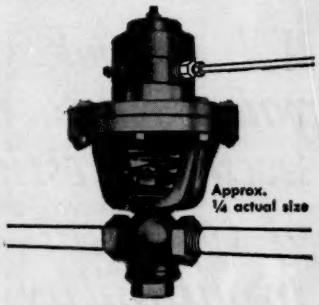

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The fast, accurate response of DURADIANT burners to the panel-mounted temperature programmer guarantees (1) consistently high quality, (2) exact matching of specifications in batch after batch, (3) quick heating, (4) unvarying temperatures, and (5) rapid cooling as desired.

The DURADIANT burners create radiant heat by burning a controlled gas-air mixture against their special, cup-shaped, refractory surfaces. Although the kettle is only ten inches above the burner setting, no charring, uneven heating or resin degradation results, since all combustion occurs within the refractory cups. There are no flame tails to cause hot spots.

Why not investigate the Selas GRADIATION approach to the batch processing of a long list of heat-sensitive materials . . . including yours? For details, write to General Industry Division.

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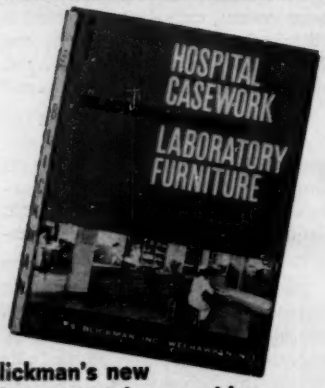

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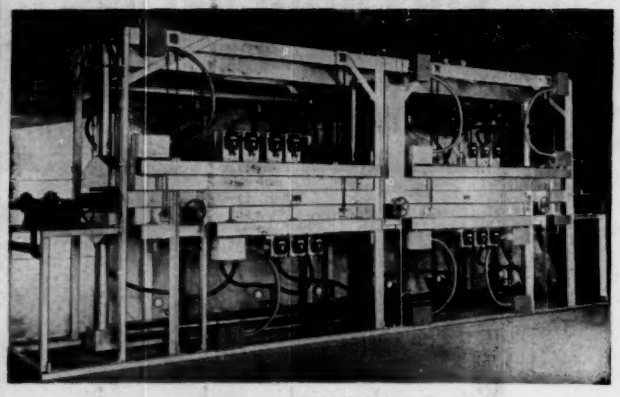

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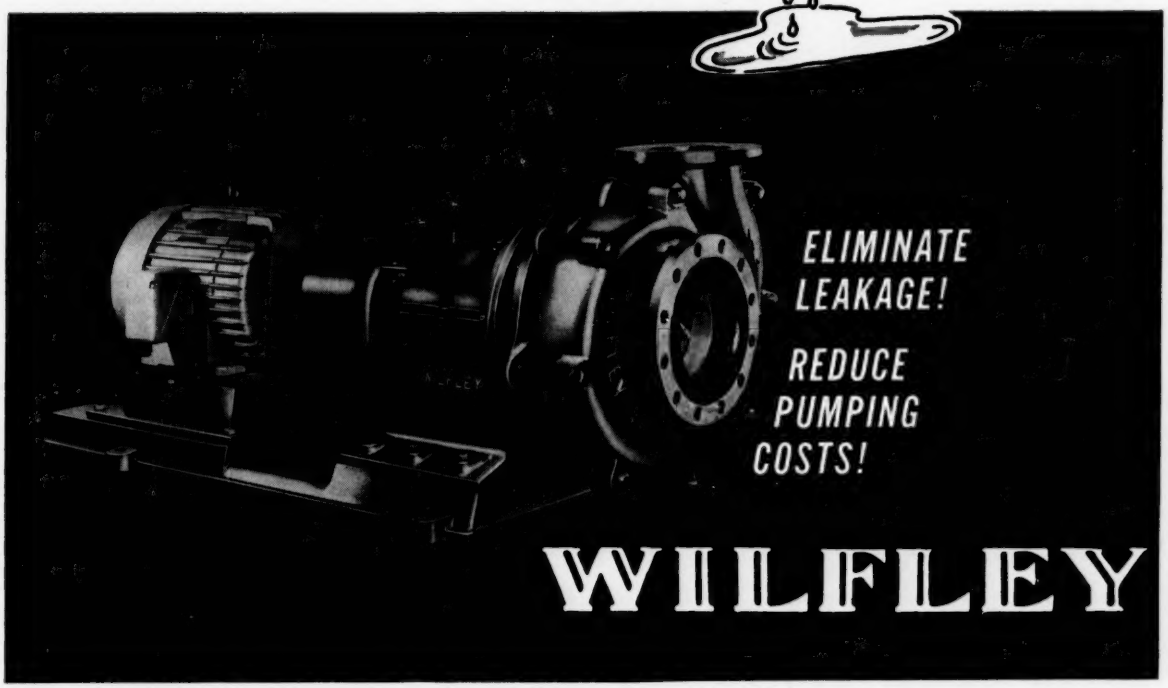

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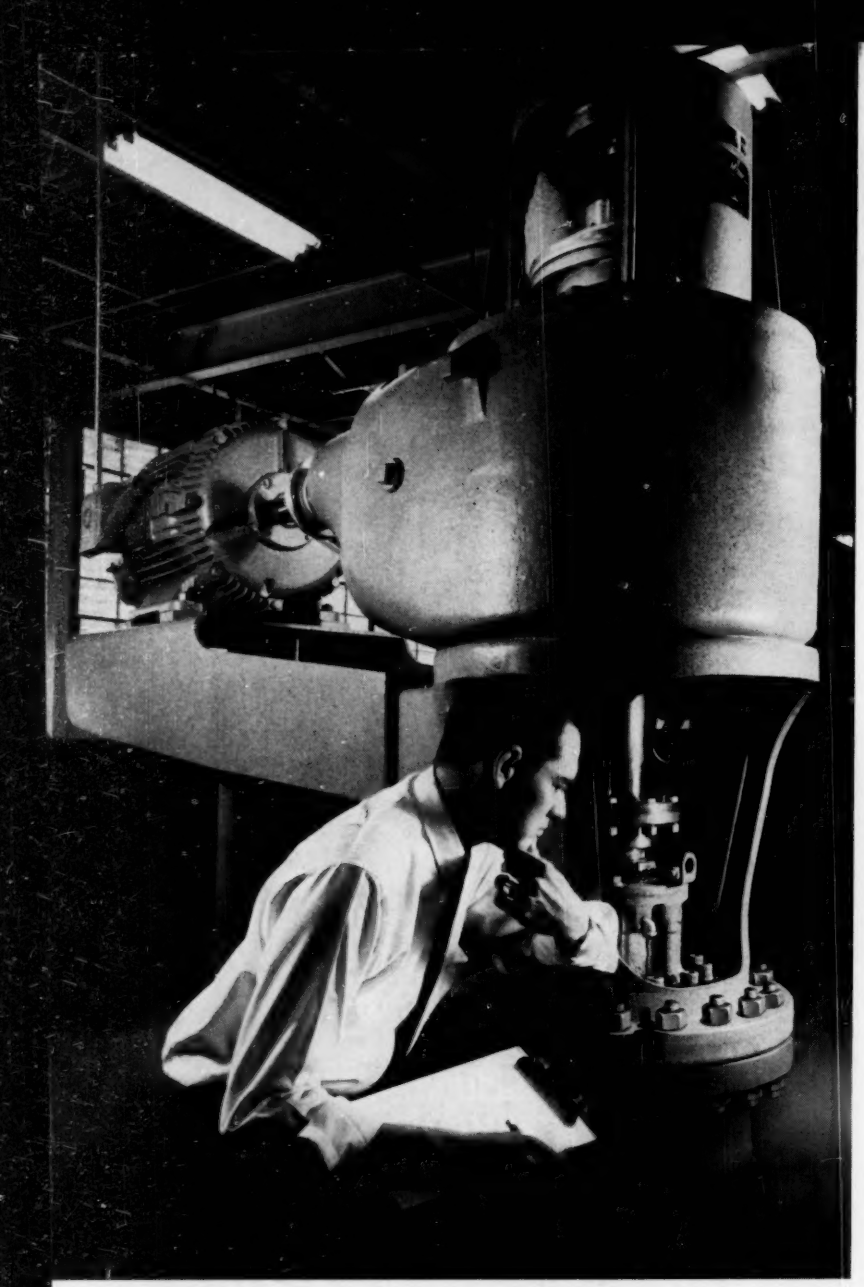


SEAL'S LEAKING!

How much will the downtime cost?

Even the best-running shaft seal on a mechanical mixer is going to wear out some day.

What you pay for the shutdown depends on how fast you can get back into production.

This is a good point to settle *before* you choose the mixer. The right answer can save you as much as *$1,000 per seal change.* (Based on conservative estimates of downtime production losses, plus direct labor cost. We've seen savings go much, much higher.)

The close-up below shows why you're ahead with a LIGHTNIN Mixer, equipped with a LIGHTNIN Rotary Mechanical Seal. Notice this patented seal is an integral cartridge unit. It saves buying separate seal parts and wondering if they'll work when you put them together.

The LIGHTNIN Seal needs no special skill to replace. It bolts in place without dismantling the mixer, without entering the tank. Aligns itself automatically. Doesn't have to be checked. You *know* it's going to work. (We never ship a seal until we've tested it statically and dynamically at rated pressure.) Gets you back onstream fast—without trouble, without tricky adjustments.

If you'd like to look further into the dollars and sense of pressure-vessel mixing with seal-equipped LIGHTNIN Mixers, your LIGHTNIN man has some interesting figures to show you. You'll find his name in Chemical Engineering Catalog and in the yellow pages of your telephone directory. Call him today. Or write directly to us.

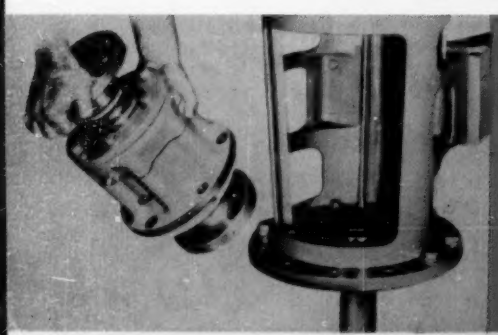
BEWARE OF "HIDDEN" MIXING COSTS

When choosing a mixer, ask yourself these six questions. Even one "yes" answer means you'll pay a needlessly high price—in lost production and in labor—to mix fluids.

To change or replace a shaft seal, will you have to:

	YES	NO
1. Check the new seal and sleeve for leaks?	☐	☐
2. Dismantle mixer or remove it from vessel?	☐	☐
3. Use skilled manpower to replace seal part by part?	☐	☐
4. Purge vessel in order to block up mixer shaft?	☐	☐
5. Uncouple mixer shaft *inside* the vessel?	☐	☐
6. Check alignment of the mixer gears, shaft, or bearings?	☐	☐

You avoid *every one* of these needless "hidden costs" when you mix with seal-equipped LIGHTNIN Mixers.



This seal could save you $1000 in case of a shutdown.

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